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# THE BORON CONTENT OF SOME OKANAGAN SOILS[1]

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The first evidence that additional boron might be needed in the Okanagan Valley was demonstrated by McLarty (4) in 1934 when he showed that where compounds containing this element had been injected into a few apple trees, the fruit on these trees was partially free from two physiological disorders, known locally as drought spot and corky core. The following year 24 apple trees were injected with either boric acid or borax. In all cases remarkable control of the above disorders was experienced. Two further methods of applying borates were tested: (1) spraying the compound onto the tree, and (2) scattering the compound on the soil about the tree. Both methods have given equally satisfactory results. Due to the costs of spraying, however, this method was discarded in favour of the soil treatment which has since been recommended to growers in the Okanagan Valley.

Experiments, both in the field and in the greenhouse, have revealed further abnormalities on different plants which were controlled either partially or completely by the application of boron compounds. Among these may be mentioned: apple measles; flat fruit; die back of apple, pear, peach, plum, and cherry; drought spot of cherry and pear; yellowing of alfalfa; heart rot of turnip; lack of kernels in wheat heads; poor growth of raspberry canes; poor growth of radish; and stunting of amaranthus.

The extent of these abnormalities in this territory caused the following recommendations to be made: (1) in 1935, to drill holes into those trees which were severely affected with either drought spot or corky core and to inject boric acid crystals; (2) in 1936, to broadcast boric acid or borax about trees severely affected with these disorders; and finally (3) in 1937, to make a general application to all orchards and fields which were being used to grow agricultural crops and which had not previously been treated. The rate of application recommended was 8 ounces per tree or 30 pounds per acre. At present, about two-thirds (15,000 acres) of the land in use in the Okanagan Valley has been treated. It is the purpose of this paper to discuss the boron content of some of the Okanagan soils, the penetration of boron in some of these soils, the effect of various solutions for the removal of boron from soils, and the amount of boron found in successive leachings.

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## REVIEW OF LITERATURE

Very few references which deal with the actual amount of boron necessary in various soils and under various climatic conditions for the healthy growth of plants have been found in the literature.

In 1935, Eaton (2) published some results obtained on boron in soils and irrigation waters and its effect on plants with particular reference to the San Joaquin Valley in California. In this case the investigations were carried out because of injury due to an excess of soluble borates. In the Okanagan Valley, Woodbridge (6) made some soil analyses in 1936 and in 1937 and from the results obtained he concluded that soil concentrations of boron (above 0.5 p.p.m. on a dry weight basis) induced by treatment with either boric acid or borax was associated with a general freedom of drought spot and corky core of apple and likewise of the disorders mentioned earlier. A correlation between low boron concentrations in the soil and incidence of disease was not established. Askew *et al.* (1) recently published a paper setting forth some of the results obtained in New Zealand where there exists a condition somewhat similar to that in the Okanagan Valley. These workers found that surface applications of borax (50 pounds per acre) had penetrated into the soil to a depth of at least thirty inches and that after three years the boron content of the soil in the main root zone was maintained at a level at least twice as high as that on the control areas. Workers in Germany (3) experimented on the leaching of borates from soil. They found that from 63 to 94% of the applied boron was leached out from 7 different soils. In each case one-half kilogram of treated soil was placed in a percolation tube, already containing one kilogram of the untreated soil and then one litre of water was drawn through the tube. From 3 to 6 leachings were required to remove most of the borates.

## EXPERIMENTAL PROCEDURE

### 1. *Collecting the Sample*

In the fall of 1938 over 100 soil samples were taken from experimental plots which had received soil applications of varying amounts of boron either in 1936 or in 1937. These plots were located in various orchards throughout the district and included a wide range of soil types. Each sample consisted of a composite of soil taken from 4 positions in one individual plot. These 4 positions were located 4 to 6 feet from a selected average tree in the plot and were midway between the irrigation furrows. Two samples were taken from each set of 4 locations, the first being a composite of the top soil, 0 to 6 inches, and the second a composite of the subsoil, 6 to 12 inches. The top soil at the 4 selected positions was loosened and a sample of 2 to 3 pounds collected. This loosened soil was removed from the hole and then the subsoil sample was collected in the same manner. In one series of samples, composites of the soil to the 24-inch depth were used. In 9 cases samples were secured at greater depths by the use of a 2-inch soil auger. These samples were taken at each 6-inch depth down to 30 inches and on one plot to 66 inches. The soils from the corresponding depths in each of the 4 holes were thoroughly mixed. The composite samples were air dried at room temperature and then screened through a $\frac{1}{4}$-inch sieve.

2. *Method of Analysis*

A sample of 300 grams of air dried soil was weighed and transferred to a $2\frac{1}{2}$-litre bottle. The soil was shaken with 1500 ml. of distilled water, and a rapid stream of carbon dioxide was bubbled through the soil-water mixture for 15 minutes. During this period the mixture was occasionally shaken. The container was stoppered and allowed to stand over night. For purposes of comparison the carbon dioxide treatment was omitted in a few cases. In its place there were substituted: (1) water alone; and (2) 1% hydrochloric acid. By drawing off the supernatant solution through a Livingston atmometer a clear extract was secured. A 1-litre aliquot of this extract was taken and evaporated on a steam bath to a convenient volume (150 ml.). With the HCl extract it was necessary to evaporate the solution nearly to dryness and then to separate the borates by distillation as for plant materials (7). From this stage the subsequent procedures were the same. The solutions were rendered slightly acid, boiled to remove any carbon dioxide, cooled, made neutral with NaOH, and then the borates present were titrated in the presence of mannitol with standard dilute sodium hydroxide (approximately 0.02 N). All samples were analysed in duplicate and the average of duplicates is reported in this paper.

The titration was carried out electrometrically using a calomel-quinhydrone set-up and balancing in all cases to a pH of 7.3 as recommended by Wilcox (5). The carbon dioxide was generated by the action of HCl (1–1) on a saturated solution of sodium bicarbonate. The gas was washed by bubbling through a solution of sodium carbonate and then through water. Blanks were run in all cases to correct for any impurities that might be found in the various lots of chemicals used. The evaporations were made in either copper or Kavalier (a boron free glass) beakers.

## RESULTS

1. *The Boron Content of Soils in Experimental Plots*

The boron contents of some representative Okanagan soils as obtained by analyses are presented in Table 1. The soils include some treated with boric acid or borax and some that received no such treatment. The type of soil, depth, and special boron treatment are indicated in the table. The boron content of the untreated soils ranged from 0.09 p.p.m. on a dry weight basis to 0.33 p.p.m., while that of the treated soils was in all cases considerably higher. For those soils which received one-half pound of either boric acid or borax per tree area (35 ft. sq.) in 1936 or in 1937 it was between 1.00 and 2.00 p.p.m. on a dry weight basis. In nearly all cases the upper 6 inches of soil contained appreciably more boron than did the 6 to 12-inch depth. Samples from the plots which had received amounts of boric acid or borax for 3 successive years contained considerably more boron than did those which had received a single application. In one case the boron content of a sample (Sample S19) which had been taken from a plot which had received 4 pounds of boric acid per year for 3 years had become 10.22 p.p.m. This amount has had as yet no detrimental effect on the tree but has severely injured the cover crop. There was, however, no consistent correlation between the amount of boron compound applied and the amount found present by analyses. For example, in sample 26 which received $\frac{1}{2}$ pound of boric acid in 1935, the boron content

TABLE 1.—THE BORON CONTENT OF SOME OKANAGAN SOILS

| Sample No. | Plot treatment | Soil type | Depth of sample in inches | Boron, p.p.m. dry weight basis |
|---|---|---|---|---|
| D1 | No treatment | Sandy loam | 0–24 | 0.14 |
| D2 | No treatment | Sandy loam | 0–24 | 0.21 |
| D3 | No treatment | Sandy loam | 0–24 | 0.10 |
| D4 | No treatment | Sandy loam | 0–24 | 0.24 |
| D5 | No treatment | Sandy loam | 0–24 | 0.33 |
| T1 | No treatment | Clay | 0–24 | 0.09 |
| T2 | No treatment | Heavy clay | 0–24 | 0.13 |
| T3 | No treatment | Silty clay | 0–24 | 0.11 |
| T4 | No treatment | Silty clay | 0–24 | 0.11 |
| T5 | No treatment | Silty clay | 0–24 | 0.14 |
| T6 | No treatment | Silt loam | 0–24 | 0.15 |
| 26 | *½ lb. boric acid 1935 | Sandy loam | 0–6 | 1.93 |
| 7 | ½ lb. boric acid 1935 | Sandy loam | 6–12 | 0.52 |
| 16 | 1 lb. boric acid 1935 | Sandy loam | 0–6 | 1.07 |
| 10 | 1 lb. boric acid 1935 | Sandy loam | 6–12 | 1.85 |
| 18 | 1½ lb. boric acid 1935 | Sandy loam | 0–6 | 5.82 |
| 19 | 1½ lb. boric acid 1935 | Sandy loam | 6–12 | 2.00 |
| 29 | 2 lb. boric acid 1935 | Sandy loam | 0–6 | 1.58 |
| 21 | 2 lb. boric acid 1935 | Sandy loam | 6–12 | 1.93 |
| 17 | ½ lb. boric acid 1935–36 | Sandy loam | 0–6 | 3.65 |
| 24 | ½ lb. boric acid 1935–36 | Sandy loam | 6–12 | 2.95 |
| 6 | 1 lb. boric acid 1935–36 | Sandy loam | 0–6 | 1.37 |
| 14 | 1 lb. boric acid 1935–36 | Sandy loam | 6–12 | 1.86 |
| 23 | 1½ lb. boric acid 1935–36 | Sandy loam | 0–6 | 4.71 |
| 27 | 1½ lb. boric acid 1935–36 | Sandy loam | 6–12 | 2.63 |
| 20 | 2 lb. boric acid 1935–36 | Sandy loam | 0–6 | 4.16 |
| 12 | 2 lb. boric acid 1935–36 | Sandy loam | 6–12 | 1.39 |
| 9 | ½ lb. boric acid 1935–37 | Sandy loam | 0–6 | 2.74 |
| 8 | ½ lb. boric acid 1935–37 | Sandy loam | 6–12 | 1.78 |
| 22 | 1 lb. boric acid 1935–37 | Sandy loam | 0–6 | 5.74 |
| 13 | 1 lb. boric acid 1935–37 | Sandy loam | 6–12 | 7.82 |
| 11 | 1½ lb. boric acid 1935–37 | Sandy loam | 0–6 | 3.70 |
| 25 | 1½ lb. boric acid 1935–37 | Sandy loam | 6–12 | 4.44 |
| 28 | 2 lb. boric acid 1935–37 | Sandy loam | 0–6 | 6.71 |
| 15 | 2 lb. boric acid 1935–37 | Sandy loam | 6–12 | 7.69 |
| 52 | ½ lb. boric acid 1936 | Clay loam | 0–6 | 2.22 |
| 51 | ½ lb. boric acid 1936 | Clay loam | 6–12 | 0.86 |
| 49 | 1 lb. boric acid 1936 | Clay loam | 0–6 | 4.07 |
| 53 | 1 lb. boric acid 1936 | Clay loam | 6–12 | 2.96 |
| 50 | ½ lb. boric acid 1936 | Clay loam | 0–6 | 1.71 |
| 48 | ½ lb. boric acid 1936 | Clay loam | 6–12 | 1.10 |
| 60 | Sprayed ¼ strength 1937 | Clay loam | 0–6 | 1.67 |
| 62 | Sprayed ¼ strength 1937 | Clay loam | 6–12 | 0.63 |
| 61 | Sprayed full strength 1937 | Clay loam | 0–6 | 2.77 |
| 58 | Sprayed full strength 1937 | Clay loam | 6–12 | 0.84 |
| 37 | ½ lb. boric acid 1936 | Fine sand | 0–6 | 0.83 |
| 38 | ½ lb. boric acid 1936 | Sand | 6–12 | 0.42 |
| 54 | ½ lb. boric acid 1936 | Sandy loam | 0–6 | 2.35 |
| 55 | ½ lb. boric acid 1936 | Fine sand | 6–12 | 1.48 |
| 57 | ½ lb. boric acid 1936 | Silt loam | 0–6 | 2.69 |
| 56 | ½ lb. boric acid 1936 | Silt loam | 6–12 | 0.54 |
| 30 | ½ lb. boric acid 1936 | Loam | 0.6 | 2.22 |
| 45 | ½ lb. boric acid 1936 | Loam | 6–12 | 1.77 |
| 46 | ½ lb. boric acid 1936 | Loam | 0–6 | 2.05 |
| 43 | ½ lb. boric acid 1936 | Loam | 6–12 | 1.18 |
| 47 | ½ lb. boric acid 1936 | Sandy loam | 0–6 | 1.53 |
| 42 | ½ lb. boric acid 1936 | Sandy loam | 6–12 | 0.75 |
| 31 | ½ lb. borax 1936 | Sandy loam | 0–6 | 2.05 |
| 39 | ½ lb. borax 1936 | Sandy loam | 6–12 | 0.42 |
| 40 | ¼ lb. boric acid 1936 | Sandy loam | 0–6 | 1.46 |

* ½ lb. per tree area (35 ft. sq.).

TABLE 1.—THE BORON CONTENT OF SOME OKANAGAN SOILS—*Concluded*

| Sample No. | Plot treatment | Soil type | Depth of sample in inches | Boron, p.p.m. dry weight basis |
|---|---|---|---|---|
| 33 | ¼ lb. boric acid 1936 | Sandy loam | 6–12 | 0.43 |
| 32 | ½ lb. boric acid 1936 | Sandy loam | 0–6 | 5.28 |
| 36 | ½ lb. boric acid 1936 | Fine sand | 6–12 | 2.14 |
| 44 | ½ lb. boric acid 1936 | Silt loam | 0–6 | 5.15 |
| 41 | ½ lb. boric acid 1936 | Loam | 6–12 | 0.90 |
| 34 | ½ lb. boric acid 1936 | Silt loam | 0–6 | 1.21 |
| 35 | ½ lb. boric acid 1936 | Loam | 6–12 | 0.23 |
| 59 | Treated 1936 | Loam | 0–6 | 1.41 |
| 64 | Treated 1936 | Loam | 0–6 | 1.64 |
| 65 | Not treated | Loam | 0–6 | 0.20 |
| 63 | Treated 1936 | Silty clay | 0–6 | 1.58 |
| J17 | ¼ lb. borax 1936 | Fine sand | Top soil | 1.36 |
| K16 | ½ lb. borax 1936 | Fine sand | Top soil | 0.30 |
| H 5 | 1 lb. borax 1936 | Fine sand | Top soil | 0.90 |
| M14 | 2 lb. borax 1936 | Fine sand | Top soil | 0.53 |
| N13 | 4 lb. borax 1936 | Fine sand | Top soil | 0.50 |
| J18 | ¼ lb. boric acid 1936 | Fine sand | Top soil | 0.80 |
| K17 | ½ lb. boric acid 1936 | Fine sand | Top soil | 0.86 |
| L16 | 1 lb. boric acid 1936 | Fine sand | Top soil | 0.84 |
| M15 | 2 lb. boric acid 1936 | Fine sand | Top soil | 0.45 |
| N14 | 4 lb. boric acid 1936 | Fine sand | Top soil | 0.60 |
| P21 | 1/16 lb. boric acid 1936–37–38 | Fine sand | Top soil | 0.43 |
| P20 | ⅛ lb. boric acid 1936–37–38 | Fine sand | Top soil | 0.49 |
| P19 | ¼ lb. boric acid 1936–37–38 | Fine sand | Top soil | 0.58 |
| P17 | ½ lb. boric acid 1936–37–38 | Fine sand | Top soil | 1.25 |
| Q17 | 1 lb. boric acid 1936–37–38 | Fine sand | Top soil | 3.89 |
| R20 | 2 lb. boric acid 1936–37–38 | Fine sand | Top soil | 3.94 |
| S17 | 4 lb. boric acid 1936–37–38 | Fine sand | Top soil | 10.22 |
| O19 | 1/16 lb. borax 1936–37–38 | Fine sand | Top soil | 0.22 |
| O18 | ⅛ lb. borax 1936–37–38 | Fine sand | Top soil | 0.39 |
| P18 | ¼ lb. borax 1936–37–38 | Fine sand | Top soil | 0.77 |
| Q16 | ½ lb. borax 1936–37–38 | Fine sand | Top soil | 0.76 |
| R17 | 1 lb. borax 1936–37–38 | Fine sand | Top soil | 0.83 |
| R19 | 2 lb. borax 1936–37–38 | Fine sand | Top soil | 2.66 |
| S18 | 4 lb. borax 1936–37–38 | Fine sand | Top soil | 1.22 |
| 110 | No treatment | Fine sand | Top soil | 0.12 |
| R 3 | No treatment | Fine sand | Top soil | 0.26 |

was found to be 1.93 p.p.m. while in sample 16 which received one pound in 1935 the boron content was only 1.07 p.p.m. This may be accounted for, at least in part, by the type of soil, by the method of application (scattering by hand), or by the method of sampling (4 points about a tree). In a few cases, particularly in the sandy soils from the Kelowna Project (Table 1, samples J17 to N14), the boron content seemed to be quite low when the amount of the application was taken into account. This may indicate that in this type of soil (shallow, light, and sandy) the boron is subject to considerable loss by leaching.

2. *Penetration of Boron in the Soil on Experimental Plots.*

In Table 2 the results of studies on the penetration of boron are presented. A fairly wide range of soil types (fine sand, sandy loam, silt loam, and clay) was chosen in order to find what effect the soil structure had on the penetration of boron. Samples were collected at each 6 inch depth down to 30 inches in 3 of the soils and in the silt loam down to 66

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TABLE 2.—PENETRATION OF BORON IN SOME REPRESENTATIVE OKANAGAN SOILS

| Sample No. | Plot treatment | Soil Type | Depth of sample in inches | Boron, p.p.m. dry weight basis |
|---|---|---|---|---|
| 130 | 4 lb. boric acid 1936 | Fine sand | 0–6 | 1.36 |
| 131 | 4 lb. boric acid 1936 | Fine sand | 6–12 | 1.15 |
| 132 | 4 lb. boric acid 1936 | Fine sand | 12–18 | 0.76 |
| 133 | 4 lb. boric acid 1936 | Fine sand | 18–24 | 0.30 |
| 134 | 4 lb. boric acid 1936 | Fine sand | 24–30 | 0.25 |
| 135 | 4 lb. borax 1936 | Sandy loam | 0–6 | 2.96 |
| 136 | 4 lb. borax 1936 | Fine sand | 6–12 | 1.05 |
| 137 | 4 lb. borax 1936 | Fine sand | 12–18 | 0.75 |
| 138 | 4 lb. borax 1936 | Fine sand | 18–24 | 0.58 |
| 139 | 4 lb. borax 1936 | Fine sand | 24–30 | 0.53 |
| 140 | 4 lb. borax 1936–37–38–39 | Fine sand | 0–6 | 4.38 |
| 141 | 4 lb. borax 1936–37–38–39 | Fine sand | 6–12 | 1.82 |
| 142 | 4 lb. borax 1936–37–38–39 | Coarse sand | 12–18 | 1.44 |
| 143 | 4 lb. boric acid 1936–37–38–39 | Fine sand | 0–6 | 17.01 |
| 144 | 4 lb. boric acid 1936–37–38–39 | Fine sand | 6–12 | 3.85 |
| 145 | 4 lb. boric acid 1936–37–38–39 | Fine sand | 12–18 | 1.00 |
| 146 | 4 lb. boric acid 1936–37–38–39 | Coarse sand | 18–24 | 0.73 |
| 125 | Check | Fine sand | 0–6 | 0.57 |
| 126 | Check | Fine sand | 6–12 | 0.62 |
| 127 | Check | Fine sand | 12–18 | 0.19 |
| 128 | Check | Fine sand | 18–24 | 0.16 |
| 129 | Check | Coarse sand | 24–30 | 0.09 |
| 105 | 2 lb. boric acid 1935–36–37–38 | Sandy loam | 0–6 | 5.74 |
| 106 | 2 lb. boric acid 1935–36–37–38 | Sandy loam | 6–12 | 4.52 |
| 107 | 2 lb. boric acid 1935–36–37–38 | Fine sand | 12–18 | 2.01 |
| 108 | 2 lb. boric acid 1935–36–37–38 | Coarse sand | 18–24 | 1.24 |
| 109 | 2 lb. boric acid 1935–36–37–38 | Coarse sand | 24–30 | 0.39 |
| 110 | 2 lb. boric acid 1935 | Sandy loam | 0–6 | 1.18 |
| 111 | 2 lb. boric acid 1935 | Sandy loam | 6–12 | 0.85 |
| 112 | 2 lb. boric acid 1935 | Fine sand | 12–18 | 0.40 |
| 113 | 2 lb. boric acid 1935 | Coarse sand | 18–24 | 0.23 |
| 114 | 2 lb. boric acid 1935 | Coarse sand | 24–30 | 0.16 |
| 147 | ½ lb. boric acid 1936 | Silt loam | 0–6 | 0.44 |
| 148 | ½ lb. boric acid 1936 | Loam | 6–12 | 0.26 |
| 149 | ½ lb. boric acid 1936 | Sandy loam | 12–18 | 0.16 |
| 150 | ½ lb. boric acid 1936 | Sandy loam | 18–24 | — |
| 151 | ½ lb. boric acid 1936 | Sandy loam | 24–30 | 0.14 |
| 152A | ½ lb. boric acid 1936 | Loam | 30–36 | 0.10 |
| 152 | ½ lb. boric acid 1936 | Loam | 36–42 | 0.09 |
| 153 | ½ lb. boric acid 1936 | Loam | 42–48 | 0.08 |
| 154 | ½ lb. boric acid 1936 | Loam | 48–57 | 0.10 |
| 155 | ½ lb. boric acid 1936 | Loam | 57–66 | 0.07 |
| 115 | ½ lb. borax 1936 | Clay | 0–6 | 0.64 |
| 116 | ½ lb. borax 1936 | Clay | 6–12 | 0.34 |
| 117 | ½ lb. borax 1936 | Clay | 12–18 | 0.27 |
| 118 | ½ lb. borax 1936 | Silty clay | 18–24 | 0.18 |
| 119 | ½ lb. borax 1936 | Silty clay | 24–30 | 0.07 |
| 120 | ½ lb. boric acid 1936 | Clay | 0–6 | 0.69 |
| 121 | ½ lb. boric acid 1936 | Clay | 6–12 | 0.49 |
| 122 | ½ lb. boric acid 1936 | Silty clay | 12–18 | 0.36 |
| 123 | ½ lb. boric acid 1936 | Clay | 18–24 | 0.13 |
| 124 | ½ lb. boric acid 1936 | Silt loam | 24–30 | 0.10 |

inches. These soils were collected in March, 1939. In the lighter soils the added boron had penetrated to the 30-inch level and the amount present at this depth had increased by 2 to 5 times that of the check. In the case of the heaviest applications (4 pounds of boric acid or borax per plot for 4 successive years) depths beyond the 18 and 24-inch levels were not obtained because of a gravel layer that was encountered, but in both of these cases the boron content at these depths (1.44 p.p.m. and 0.73 p.p.m.) was several times that of the check (0.16 and 0.09 p.p.m.). In the loam soil, where samples down to the 66-inch depth were obtained, the boron had not penetrated beyond the 30-inch depth. In this soil no difference existed in the boron content of any of the depths from 30 to 66 inches. The average for these depths was 0.09 p.p.m. In the clay soils, the lower depths contained only 0.07 and 0.10 p.p.m. which are the same values as obtained for untreated soils. These results may be taken to indicate that in clays the boron had not penetrated beyond the 30-inch depth.

3. *Comparison of the Amount of Boron Obtained with Different Extracting Solutions*

A comparison was made of 3 extracting solutions for boron in soils; water; water saturated with carbon dioxide; and 1% hydrochloric acid. The amount of boron extracted by the above solutions from the same soil samples are shown in Table 3. No significant difference occurred between water and water saturated with carbon dioxide, but with the 1% hydrochloric acid solution there was from 1.5 to 2.5 times as much boron extracted. For example in Sample 40, water and water saturated with carbon dioxide removed 1.28 p.p.m. and 1.42 p.p.m. respectively whereas a 1% hydrochloric acid solution removed $1\frac{1}{2}$ times as much, namely 2.12 p.p.m. boron from the soil on a dry weight basis. It is not known to what this increase is due. It may be due to the releasing of borates, fairly insoluble in water but soluble in acid, or to a change in soil structure, particularly of colloidal particles, brought about by the action of the acid used.

TABLE 3.—COMPARISON OF VARIOUS EXTRACTING SOLUTIONS FOR BORON IN OKANAGAN SOILS

| Sample No. | Soil type | Boron, p.p.m. dry weight basis | | |
|---|---|---|---|---|
| | | Water | Water — $CO_2$ | 1% HCl |
| 6 | Sandy loam | 1.29 | 1.36 | — |
| 30 | Silt loam | 2.62 | 2.39 | — |
| 39 | Loam | — | 0.50 | 1.10 |
| 40 | Loam | 1.28 | 1.42 | 2.12 |
| 48 | Loam | 1.05 | 1.10 | 1.17 |
| 52 | Clay | 2.02 | 2.22 | 3.38 |
| 54 | Sandy loam | 2.78 | 2.70 | — |
| 57 | Silt loam | 2.78 | 2.69 | — |
| 59 | Silt loam | 1.44 | 1.41 | 2.63 |
| 61 | Silt loam | 2.51 | 2.68 | 3.25 |
| 63 | Silty clay | 1.55 | 1.58 | 3.55 |
| 65 | Loam | 0.18 | 0.20 | 0.30 |
| Q16 | Fine sand | 0.77 | 0.77 | — |
| M14 | Fine sand | 0.55 | 0.53 | — |
| P17 | Fine sand | 1.57 | 1.42 | — |
| P18 | Fine sand | 0.78 | 0.77 | — |
| K17 | Fine sand | — | 0.86 | 1.04 |
| K16 | Fine sand | — | 0.30 | 0.75 |

4. *The Amount of Boron Removed in Successive Extractions*

The amounts of boron present in successive water extractions are given in Table IV. In this experiment 300 gm. of a soil sample were shaken with 1500 ml. of water, allowed to stand over-night, and then 1000 ml. of the solution was removed by suction through the Livingston atmometers as described above. A further 1000 ml. of water was then added to replace that removed, shaken, and allowed to stand over-night as before. This procedure was repeated until 6 successive litres of extract had been obtained. Each extract was analysed separately. At the first extraction $\frac{2}{3}$ of the solution was removed, and if all the boron originally present could be considered as soluble, only $\frac{1}{3}$ should remain. The results as exemplified in Sample P18 (Table 4) show that this consideration did not hold. In the first extract of this sample the boron content was 0.78 mg. and if $\frac{1}{3}$ was to remain there should be 0.39 mg. present in the remaining 500 ml. of soil solution. This solution was then diluted to 1500 ml. and 1000 ml. withdrawn as described above. In the second extract there would be expected $\frac{2}{3}$ of 0.39 mg. *i.e.* 0.26 mg. However, the results of analysis indicate that the amount found in this second extract was 0.34 mg., or 0.08 mg. more than expected. By following the above reasoning through 6 extracts a theoretical total for Sample P18 would be calculated as 1.17 mg. whereas the amount actually found was 1.84 mg. These results indicate that by a succession of 6 extracts the amount of boron removed from a sample would be over $1\frac{1}{2}$ times as much as that which would be indicated by an analysis made on a single extraction. The experiment thus brings into question the reliability of a single extraction method of analyses for boron in soils. The results might be taken to imply that a certain amount of boron is tied up in the soil to a more or less degree. It is not known whether this boron is available to plants but since it was soluble in successive leachings it seems reasonable to expect that it might be.

TABLE 4.—AMOUNT OF BORON REMOVED BY SUCCESSIVE WATER EXTRACTIONS

| Sample No. | Soil type | Boron extracted—mg. dry weight basis | | | | | | | Theoretical total |
|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 5th | 6th | Total | |
| P18 | Fine sand | 0.78 | 0.34 | 0.25 | 0.19 | 0.14 | 0.14 | 1.84 | 1.17 |
| P19 | Fine sand | 0.83 | 0.44 | 0.30 | 0.30 | 0.18 | 0.11 | 2.16 | 1.24 |
| 25 | Sandy loam | 3.66 | 2.17 | 0.97 | 0.69 | 0.40 | 0.21 | 8.10 | 5.49 |
| 26 | Sandy loam | 1.54 | 0.92 | 0.55 | 0.37 | 0.29 | 0.24 | 3.91 | 2.31 |
| 30 | Silt loam | 2.62 | 1.48 | 0.88 | 0.56 | 0.46 | 0.32 | 6.32 | 3.93 |
| 40 | Loam | 1.03 | 0.74 | 0.47 | 0.33 | 0.29 | 0.24 | 3.10 | 1.54 |
| 44 | Clay | 3.36 | 2.35 | 1.67 | 1.30 | 0.96 | 0.94 | 10.58 | 5.04 |
| 46 | Silt loam | 2.61 | 1.56 | 0.87 | 0.47 | 0.39 | 0.40 | 6.30 | 3.92 |
| 47 | Silt loam | 0.94 | 0.65 | 0.51 | 0.38 | 0.32 | 0.26 | 3.06 | 1.41 |
| 52 | Clay | 2.02 | 1.11 | 0.85 | 0.39 | 0.43 | 0.32 | 5.12 | 3.03 |
| 54 | Sandy loam | 2.26 | 1.32 | 0.81 | 0.56 | 0.46 | 0.36 | 5.77 | 3.39 |
| 57 | Silt loam | 2.73 | 1.38 | 0.80 | 0.62 | 0.50 | 0.40 | 6.43 | 4.10 |

## SUMMARY

1. The results of analyses for the boron content of representative Okanagan soils from experimental plots are presented.

2. From 9 of the experimental plots, soils were taken to a depth of 30 inches and in one case to 66 inches. Analyses for boron from the various

depths indicated that in lighter soils and where heavier amounts of boron compounds had been applied the boron had penetrated to at least 30 inches. In heavier soils and where lesser amounts of the compounds had been applied the boron had not penetrated beyond 24 inches.

3. A comparison of various extracting solutions for boron in soil was made. For the extraction of boron no difference exists between water alone and water saturated with carbon dioxide. A 1% solution of hydrochloric acid extracted $1\frac{1}{2}$ to $2\frac{1}{2}$ times as much boron as did the others.

4. With 6 successive extractions, using water alone, the theoretical amounts of boron extracted were exceeded from $1\frac{1}{2}$ to 2 times the amounts calculated.

## ACKNOWLEDGMENTS

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# RECENT STUDIES ON THE NATURE OF SOIL ORGANIC PHOSPHORUS[1]

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Investigation of the organic phosphorus present in Quebec soils was begun at Macdonald College in 1935, and has been proceeding more or less continuously since that time. It is the purpose of this paper to give a general outline of the results that have been obtained. Part of the work mentioned herein has already been published or submitted for publication, but most of it has not been reported previously. In either event, it is not the purpose to go into the details of experimental work, but rather to attempt a coherent account of research work which is in progress.

The probable importance of the problem under consideration may be made clear by reference to the phosphorus status of the majority of Quebec soils. As a rule these soils are fairly rich in total phosphorus, but markedly deficient in available phosphorus as judged by their content of readily soluble phosphate and by crop response to applications of super-phosphate. In the majority of these soils a relatively large proportion, 50% or more, of the total phosphorus present is organically combined. It would seem therefore that the organic fraction does not constitute a readily available form of phosphorus in these soils.

The work undertaken has been mainly directed toward the identification of the organic compounds in which such a large part of the soil phosphorus is combined. Following methods previously used by other workers, notably the late E. C. Shorey (7), but recording yields and phosphorus content, Wrenshall and McKibbin (10) separated a large proportion of the organic phosphorus in the "nucleic acid" fraction. The composition of the material obtained appeared to justify the conclusion that it was composed largely of adenine and uracil nucleotides. The amount of ether soluble phosphorus found in soil was negligible, and no indications of the presence of other organic phosphorus compounds were noted at that time. It was concluded that nucleotides constituted the most important organic phosphorus fraction present in the soils studied.

The significance of such a conclusion may be seen from consideration of a single case. One of the surface soils which has been under investigation contains (given approximately in round figures) 12% of organic matter, 0.5% of nitrogen, and 0.14% of organic phosphorus. If it be assumed that all of this phosphorus is in forms similar to nucleic acids, then it is evident that these compounds make up over 10% of the soil organic matter, and probably contain over 30% of the soil nitrogen. Whatever the nature of these organic phosphorus compounds may be, they make a significant contribution to the total organic matter of the soil, and must be regarded as important from the standpoint of the constitution of soil organic matter.

[1] Contribution from the Faculty of Agriculture of McGill University, Macdonald College, Que., with assistance from the National Research Council of Canada. Macdonald College Journal Series No. 135. Read to the Soils Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.

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To accumulate to the extent indicated above these compounds must be relatively stable under the conditions existing in the soils. Like soil organic matter as a whole, however, they are doubtless subject in some degree to decomposition by micro-organisms, and from this standpoint may be considered as a potential source of plant nutrients. Wrenshall and McKibbin (11) found that pasture plants grown in pot cultures obtained considerably more phosphorus than could be accounted for on the basis of readily soluble phosphate, and concluded that the extra phosphorus probably came from the organic phosphorus compounds. As indicated earlier, the contribution from this source is ordinarily not great enough to give adequate supplies of phosphate to crops. Probably the value of organic phosphorus would be enhanced if decomposition processes could be speeded up. It seems likely that the apparent improvement in phosphate status often produced by liming is due in some measure to an increase in the rate of decomposition of these constituents.

It appears to be well established that most organic phosphorus compounds, when added to soil, constitute excellent sources of available phosphorus. In this connection the work of Heck and Whiting (3, 9) is of interest, and other examples could be cited. Although it has not been demonstrated to what extent decomposition takes place, the concensus of opinion seems to be that the organic phosphorus compounds are not absorbed as such by the plants, but are broken down with the release of phosphate which the plants can utilize. If this is so, then the behaviour of the organic phosphorus found in soil is very different from that of known organic phosphorus compounds; no satisfactory explanation of its marked accumulation in soil has ever been given, and a great deal remains to be explained about the nature and behaviour of this material.

It seemed that the success of further work on the problems relating to soil organic phosphorus would depend to a large extent upon being able to distinguish quantitatively between organic and inorganic phosphorus, not only in the soil as a whole, but also in the variety of extracts containing soil organic matter which must be handled in any attempt to fractionate soil organic phosphorus. Attention was therefore diverted to the problems of phosphate colorimetry in highly coloured solutions, and a considerable degree of success has been attained through the application of a photoelectric colorimeter with light filters. The behaviour of the ceruleomolybdate colour under a variety of conditions has been studied (1, 8), and a method of determining soil organic phosphorus has been described (12). Photoelectric colorimetry is proving to be a most effective aid in the study of soil organic phosphorus problems.

Since the organic phosphorus-bearing material obtained from soil by different workers is believed to be of nucleic acid nature, it was of the greatest interest to compare its behaviour in soil with that of plant nucleic acid. Further, since adenine and uracil were the only bases found in the material from Quebec soil (10) it was of interest to compare the decomposition of the individual nucleotides to see whether adenylic and uridylic acids were relatively stable. Accordingly, a quantity of soil "nucleic acid" was prepared from Ste. Clothilde muck. It may be mentioned here that the yields of material obtained, both in this experiment and in subsequent attempts with other soils, were very disappointing, and the number of decomposition experiments have been limited by lack of the material isolated

from soil. The four nucleotides, guanylic, adenylic, cytidylic, and uridylic acids, were prepared from yeast nucleic acid by the method of Levene and Bass (4). A series of experiments was then performed in which the decomposition of these materials in moist soil was traced by analyses for inorganic and organic phosphorus. A summary of the results obtained is given in Table 1.

TABLE 1.—DECOMPOSITION OF ORGANIC PHOSPHORUS COMPOUNDS ADDED TO MACDONALD COLLEGE LOAM

| Material added | Estimated percentage decomposition | Material added | Estimated percentage decomposition |
|---|---|---|---|
| Yeast nucleic acid | 126.4 | Cytidylic acid | 110.9 |
| Soil "nucleic acid" | 27.3 | Calcium uridylate | 97.3 |
| Guanylic acid | 92.4 | Inorganic phosphate | 99.6* |
| Adenylic acid | 110.9 | | |

* Recovery of inorganic phosphate added.

It is evident that yeast nucleic acid and the four nucleotides are readily decomposed by the soil micro-organisms. The decomposition of these materials apparently took place within the first week. The experimental error involved is so great that it would be rash to interpret the results too closely, but it appears likely that the compounds were completely broken down. The soil "nucleic acid", on the other hand, was relatively stable and was decomposed only to a limited extent after 12 weeks.

The above experiment fails to indicate any relative stability of adenylic and uridylic acids which could account for the accumulation of soil organic phosphorus. In fact, the results obtained cast considerable doubt on the identity of the material separated from soil. It seems likely that the latter bears only a superficial resemblance to nucleic acid and its derivatives. Of course, the comparison is not entirely a fair one, since the soil material was very impure and could conceivably be bound up with other substances in such a way as to render it less subject to attack. Gulland and Jackson (2) have observed that in the enzymic hydrolysis of yeast nucleic acid never more than 75% of the total phosphate was liberated. The data in Table 1 do not bear this out, but probably it would be pushing the interpretation too far to say that the possibility of there being an undecomposed residue is excluded. It must be admitted that the origin and nature of the soil organic phosphorus remains very obscure.

The Macdonald College loam is a fertile soil with a relatively low content of organic phosphorus, and may be considered to possess a high ability for breaking down organic phosphorus compounds. In a comparable experiment with an infertile podsol soil, the results indicated that yeast nucleic acid was only 10% decomposed in 3 weeks, while the soil "nucleic acid" was not appreciably attacked. Evidently soils differ widely in their capacity to break down nucleic acid compounds, and there may be some basis for expecting material of this type to persist in the podsol soils.

Recent evidence has indicated that at least two different forms of organic phosphorus are present together in soil. It has been found that

heating soil with strong alkali breaks down a part of the organic phosphorus giving a corresponding increase in inorganic phosphate. The remainder of the organic phosphorus is extremely resistant to alkaline hydrolysis. Thus, refluxing for 4 hours with 1% sodium hydroxide gives the same amount of break-down as refluxing for 24 hours with 5% sodium hydroxide. These two forms are being termed the decomposable and non-decomposable fractions respectively. It is not possible as yet to assign any specific chemical significance to this fractionation, but it is well known that organic phosphorus compounds differ widely in their stability towards alkali (5, 6), and it is altogether likely that the observed behaviour denotes a real chemical difference. Neither is it possible to say at present what practical significance may be attached to these fractions. However, soils differ appreciably in the proportions of these organic phosphorus fractions as is shown by the data in Table 2.

TABLE 2.—FRACTIONATION OF THE ORGANIC PHOSPHORUS IN DIFFERENT SOILS BY REFLUXING WITH FIVE PER CENT SODIUM HYDROXIDE

| Soil | Total organic phosphorus —p.p.m. | Percentage decomposed | Percentage undecomposed |
|---|---|---|---|
| Macdonald College: Loam—plow depth | 450 | 44.4 | 55.6 |
| Halliday loam: $A_1$ horizon | 1360 | 41.2 | 58.8 |
| Stanstead loam: A horizon | 340 | 11.8 | 88.2 |

The release of phosphate from the soil compounds by acid hydrolysis has also been studied but to a lesser extent. It has not yet been shown that any definite fractionation could be effected in this way. However, it was observed that part of the soil organic phosphorus is very resistant to acid hydrolysis and complete dephosphorylation is very difficult to attain even by prolonged refluxing with strong acid. Such behaviour might be expected if the two or more compounds concerned are susceptible to acids, but differ widely in their rates of hydrolysis.

It was stated earlier that difficulty has been experienced in obtaining satisfactory yields of soil "nucleic acids", and this has led to further study of the separation of this material from soil. The usual procedure is, briefly, to leach the soil with 1N. hydrochloric acid, and then extract with hot, 4% ammonium hydroxide. Excess ammonia is evaporated from the extract, and the "humic acid" is precipitated by acidification. The filtrate from the "humic acid" is evaporated to small volume, and the "nucleic acid" fraction is precipitated by the addition of several volumes of alcohol. It is possible to follow the organic phosphorus through these steps by means of the photoelectric method, and this has been done in several trials with different soils and with variations in the procedure.

The only variation in the procedure which has been found to produce a significant effect on the distribution of organic phosphorus among the

fractions is the addition of ammonium oxalate prior to precipitating the "humic acid". Figure 1 illustrates the procedure and shows the distribution of organic phosphorus among the several fractions as found in typical experiments. The figures in squares give the distribution found when oxalate was present.

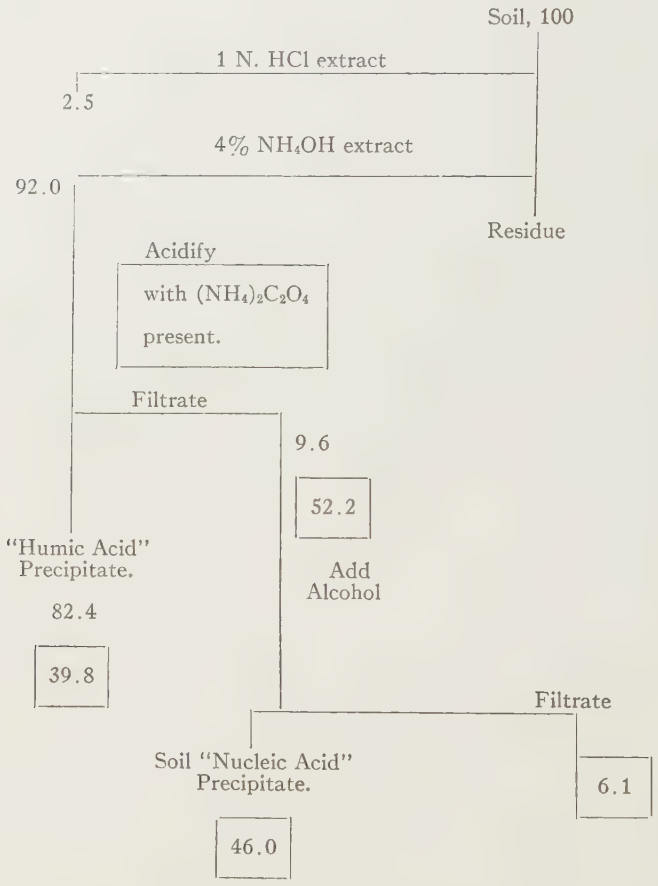


FIGURE 1. Distribution of soil organic phosphorus among various fractions obtained in the separation procedure.

These results show that, in the normal procedure, most of the organic passes into the "humic acid" precipitate. The proportion in the filtrate was found to vary from soil to soil, but was particularly low in mineral soils, where it never exceeded 15% of the total amount in the alkaline extract. Under these circumstances a low percentage yield is inevitable. However, when oxalate was present the amount of organic phosphorus passing into the filtrate was strikingly increased, and a large proportion of this could be separated by alcohol precipitation. Thus it should now be possible to obtain larger amounts of the soil "nucleic acid" than have been available for study up to the present.

## SUMMARY

Organic phosphorus compounds are important components of soil organic matter from the standpoint of the quantities present.

Despite the fact that part of the soil organic phosphorus bears a chemical similarity to nucleic acids, it differs greatly from such compounds in its susceptibility to decomposition in the soil. The soil compounds are very resistant to decomposition by soil micro-organisms.

A definite fraction of the soil organic phosphorus is highly resistant to decomposition by alkaline hydrolysis. Also it is very difficult to split off all the phosphate by acid hydrolysis.

An improved procedure, by which higher yields of the soil "nucleic acid" fraction are obtained, has been worked out.


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The attention of agricultural workers in Canada is directed toward the immense amount of valuable information on Canadian agriculture contained in Volume VIII of the Census of 1931, as compiled by the Dominion Bureau of Statistics, Ottawa, Canada. This information was secured and published at a very considerable expense to the Government and it is greatly to be desired that it should be more widely used by scientific agriculturists, particularly agricultural economists.

# THE EFFECT OF ALKALI SALTS ON PLANT GROWTH[1]

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The rehabilitation program outlined under the Prairie Farm Rehabilitation Act includes the development of irrigation projects varying in size from a few acres to several thousand acres. Many of the areas that offer possibilities of development are creek and river flats or other low lying lands. Such areas often contain more water soluble salts than the adjacent higher land.

Reference to the soil map of Saskatchewan (4) shows that most of the alkali areas are found in the brown and dark brown soil zones, which are indicative of a low rainfall. Many of these areas are suitable for irrigation in so far as potential water supply and topography are concerned. The salt concentration of the soil in these areas may have a definite influence on the yield and the kind of crop that can be grown.

Mitchell (2) states that the sulphates of calcium, magnesium and sodium are the predominant salts found in the soils of Saskatchewan. The results of numerous analyses at this Laboratory of soil samples from southwestern Saskatchewan have been in keeping with this statement. Practically all samples contain some bicarbonate, though free carbonate is of infrequent occurrence. The chloride content is generally quite low, seldom occurring in sufficient concentration to be considered toxic. The major anion in practically all samples is sulphate, the relative proportion increasing in the samples of high concentration. Wide variations are found in the proportions of calcium, magnesium and sodium, any one of which may be the major cation. In some cases the water soluble calcium is sufficiently high to yield an extract that is considered saturated in respect to calcium sulphate.

The amount of water soluble salts that may be present without causing serious damage to the crop varies according to the kind of salts present. When calcium sulphate constitutes the major portion of the salts, the limit of tolerance is generally higher than when this salt is present only in a relatively small amount.

The data presented by Kearney and Scofield (1) show the relative resistance of various crops to alkali salts composed chiefly of sulphates. They list barley as being more tolerant than oats or wheat, and sweet clover more resistant than alfalfa. Shutt (3) gives the same order of tolerance, which has been more or less accepted by men working in this field.

The data presented in this paper deal with the effect of water soluble salts on the yield of alfalfa, oats and wheat. These crops were grown in a greenhouse on soils of different salt concentration.

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[1] Contribution from the Experimental Farms Service, (P.F.R.A.), Dominion Department of Agriculture, Ottawa. Read to the Soils and Horticultural Groups of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.

[2] Senior Soil Specialist.

[3] Graduate Assistant, (deceased Sept. 30, 1939).

## EXPERIMENTAL

The soil used for these experiments was alluvial material derived mainly from weathered shales that were high in salts. It is classed as a very heavy clay, which bakes readily, forming wide, deep cracks when dry. The rate of percolation is very slow after the soil becomes saturated. The water soluble salts in the surface layer of this area vary from less than 0.1 to over 1.0%. A layer of high salt concentration is generally found within 36 inches of the surface in the areas of low surface concentration.

The original plant cover consisted of greasewood *(Sarcobatus vermiculatus)*, sage brush *(Artemisia cana)* and Bluejoint *(Agropyron Smithii)*. The greasewood was found in the areas of high salt content.

Two samples of soil were secured from adjacent locations, one having a salt concentration of 0.157% and the other 1.096%. Six series of soils were set up, using the 2 original soils as the extremes and varying the salt content of the intermediate series by mixing different proportions of the original samples. After thorough mixing, a sample of each soil was taken for analysis.

Alfalfa, oats and wheat were used as experimental crops, each being grown on the complete series of 6 soils. Glazed gallon crocks were used as containers, each series being in triplicate and each crock containing 3 plants.

## COMPOSITION OF SOILS

The data in Table 1 show the organic matter, nitrogen, total and easily soluble phosphorus, and pH of the 2 original soils. The organic matter and nitrogen were slightly higher in soil 1 than in soil 6. Both soils contained a high amount of easily soluble phosphorus and were quite alkaline in reaction.

TABLE 1.—ORGANIC MATTER, NITROGEN AND PHOSPHORUS IN THE ORIGINAL SOILS

| Soil No. | Organic matter | Nitrogen | Total phosphorus | Easily sol. phosphorus | pH |
|---|---|---|---|---|---|
| | % | % | % | p.p.m. | |
| 1 | 2.701 | 0.164 | 0.070 | 204 | 8.4 |
| 6 | 2.021 | 0.114 | 0.069 | 194 | 8.4 |

The composition of the water soluble salts for the complete series of 6 soils is given in Table 2. Numbers 1 and 6 refer to the original soils, the

TABLE 2.—COMPOSITION OF THE WATER EXTRACTS OF THE SOIL USED IN POT CULTURES
(Basis of dry soil)

| | No. 1 | | No. 2 | | No. 3 | | No. 4 | | No. 5 | | No. 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | M.e. | % | M.e. | % | M.e. | % | M.e. | % | M.e. | % | M.e. |
| Carbonate | – | – | – | – | – | – | – | – | – | – | – | – |
| Bicarbonate | 0.088 | 1.44 | 0.077 | 1.26 | 0.054 | 0.89 | 0.042 | 0.69 | 0.036 | 0.59 | 0.027 | 0.44 |
| Chloride | 0.008 | 0.24 | 0.016 | 0.46 | 0.024 | 0.68 | 0.028 | 0.80 | 0.038 | 1.07 | 0.051 | 1.45 |
| Sulphate | 0.016 | 0.32 | 0.106 | 2.21 | 0.189 | 3.94 | 0.288 | 6.00 | 0.473 | 9.85 | 0.682 | 14.21 |
| Calcium | 0.005 | 0.25 | 0.006 | 0.30 | 0.008 | 0.40 | 0.011 | 0.57 | 0.021 | 1.07 | 0.042 | 2.10 |
| Magnesium | 0.001 | 0.08 | 0.001 | 0.11 | 0.007 | 0.63 | 0.008 | 0.70 | 0.017 | 1.39 | 0.031 | 2.55 |
| Sodium* | 0.039 | 1.68 | 0.081 | 3.52 | 0.103 | 4.48 | 0.148 | 6.24 | 0.208 | 9.05 | 0.263 | 11.45 |
| Total | 0.157 | | 0.287 | | 0.385 | | 0.525 | | 0.793 | | 1.096 | |

* Sodium determined by difference.

others being mixtures of these two. A 1 to 5 water extract was made of each soil and the various constituents determined by standard methods. Sodium was determined by difference in each case. Results are reported as percentage and as milliequivalents based on the dry soil. The data show the absence of carbonates and the low content of bicarbonate and chloride. The preponderance of sulphates in soils of high salt concentration is shown by the data for soil 6.

## RESULTS

### *Alfalfa*

Data are presented in Table 3 showing the yields for 5 consecutive crops of alfalfa. The yields are reported in grams per crock (average of triplicates) and on a percentage basis rating the crop on soil 1 as 100. The results for the 5 crops show a gradual decrease in yield with increased salt concentration in the soil. The first crop on soil 6 was 35% of that on soil 1, while the fourth crop on soil 6 yielded 67% of that on soil 1. The second crop on soil 1 was the highest while the fifth crops were the largest on soils 4, 5 and 6. The age of plants may have accounted for this increased yield on the soils of high salt content in that alfalfa plants are considered more resistant as they become older. Some difficulty was experienced in securing a stand on soils 5 and 6, the young seedling being killed owing to an accumulation of salts at the surface. When the plants were watered, these salts dissolved and subjected the plants to higher concentratives than were normally present in the soil.

An application of triple superphosphate, at the rate of 75 pounds per acre, was made after cutting the second crop. There was no consistent increase in yield in the third crop that could be attributed to the fertilizer. Ammonium phosphate (16–20–0) was applied at the rate of 100 pounds per acre to all the soils after cutting the fourth crop. The effect of this fertilizer is evident in the increased yield of the fifth crop. The crop on soil 1 showed the greatest percentage increase and that on soil 5 was second highest, indicating that the effect of the fertilizer was approximately the same in all cases.

From the data in Table 3 it would appear that the yield of alfalfa on land containing 1.0% of water soluble salts would be from 50 to 60% of

Table 3.—Effect of salt concentration on the yield of alfalfa

| Soil No. | Salt concentration, % | 1st crop | | 2nd crop | | 3rd crop | | 4th crop | | 5th crop | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gms.* | Basis of 100 | Gms. | Basis of 100 | Gms. | Basis of 100 | Gms. | Basis of 100 | Gms. | Basis of 100 |
| 1 | 0.157 | 8.16 | 100 | 10.65 | 100 | 9.97 | 100 | 7.56 | 100 | 10.27 | 100 |
| 2 | 0.287 | 6.23 | 76 | 9.33 | 88 | 10.23 | 104 | 7.63 | 101 | 8.77 | 86 |
| 3 | 0.385 | 5.36 | 66 | 7.33 | 69 | 7.83 | 79 | 6.70 | 89 | 7.67 | 75 |
| 4 | 0.525 | 4.73 | 58 | 5.98 | 56 | 6.03 | 60 | 5.83 | 77 | 7.10 | 69 |
| 5 | 0.793 | 3.26 | 40 | 5.45 | 51 | 5.63 | 56 | 5.13 | 68 | 6.77 | 66 |
| 6 | 1.096 | 2.83 | 35 | 4.53 | 43 | 5.13 | 51 | 5.03 | 67 | 6.30 | 61 |

* Average of three crocks.
3rd crop fertilized with triple superphosphate at 75 pounds per acre.
5th crop fertilized with ammonium phosphate (16–20–0) at 100 pounds per acre.

that on a similar type of soil which was low in salts. The salt concentration of 0.385% (soil 3) caused a reduction in yield of 11 to 34%, indicating that fair returns could be expected from similar land containing up to 0.4% salts. Kearney and Scofield (1) list 0.4% as the upper limit of salt concentration for good growth of alfalfa.

Analyses were made of the second crop to determine if the salt concentration had any appreciable effect on the composition of the plants. Some small differences were observed but these were not sufficient to indicate that the feeding value had been impaired or improved. Part of this variation may have been caused by the age of the plant at the time of cutting, for variations in maturity as indicated by the time of flowering were observed between different series and plants in the same series.

*Oats*

Data are presented in Table 4 showing the yield of grain and straw for 2 consecutive oat crops grown on the 6 soils. The yields are reported on the percentage basis considering the crop on soil 1 as 100. The results show the same general decrease in yield at the higher salt concentrations as obtained with alfalfa, Table 3. The second oat crop shows a greater decrease on the last three soils than for the first crop. In both cases, the crop was reduced over 50% when grown on soil containing 1.0% of salt.

TABLE 4.—EFFECT OF SALT CONCENTRATION ON YIELD OF OATS AND WHEAT

| Soil No. | Salt concentration % | Oats | | | | Wheat | |
|---|---|---|---|---|---|---|---|
| | | 1st crop | | 2nd crop | | Grain | Straw |
| | | Grain | Straw | Grain | Straw | | |
| 1 | 0.157 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2 | 0.287 | 97 | 83 | 74 | 70 | 76 | 80 |
| 3 | 0.385 | 78 | 69 | 68 | 56 | 83 | 66 |
| 4 | 0.525 | 62 | 70 | 41 | 44 | 78 | 57 |
| 5 | 0.793 | 51 | 62 | 38 | 44 | 57 | 39 |
| 6 | 1.096 | 47 | 48 | 32 | 41 | 23 | 17 |

The results indicated that 0.4% of salts was approximately the upper limit of salt concentration that permitted fair growth under the conditions of this experiment. In another experiment using a similar soil containing 0.421% of salts (0.216% sodium sulphate), very poor growth of oats was obtained. Soil from an area containing 0.463% of salts (0.275% calcium sulphate) produced good crops of oats and alfalfa.

*Wheat*

Data included in Table 4 show the effect of salt concentration on the yield of wheat. The same general effect was obtained as with the other crops. The very low percentage yield for soil No. 6 (1.096% salt) may indicate that wheat is not as resistant as oats to high concentrations of salts.

*Field Observations*

Extreme variations in growth were observed in the oat crop grown on the field from which the soil samples for the pot cultures were obtained. Some of the areas were quite sharply defined, excellent growth and very poor growth being observed within a distance of 6 to 10 feet. The areas of poor growth were practically bare, there being only a few short spindly plants.

Two locations were selected where this extreme variation was apparent and soil samples collected for analysis. The samples at each location were taken within 6 feet of each other. The data in Table 5 show the total water soluble salts at different depths for each location. The amount of salts present in the areas of poor growth was definitely toxic. The results also show the wide variation that may be found under natural field conditions.

TABLE 5.—SALT CONCENTRATION IN SOILS FROM AREAS OF GOOD AND POOR GROWTH OF OATS

| Depth inches | Location 1 | | Location 2 | |
|---|---|---|---|---|
| | Good growth, % total salts | Poor growth, % total salts | Good growth, % total salts | Poor growth, % total salts |
| 0–6 | 0.129 | 0.435 | 0.103 | 2.240 |
| 6–12 | 0.159 | 2.120 | 0.229 | 2.430 |
| 12–24 | 0.148 | 1.980 | 1.118 | 2.349 |

## SUMMARY

Data are presented showing the effect of different concentrations of water soluble salts on the growth of alfalfa, oats and wheat.

Six soils containing from 0.157 to 1.096% of water soluble salts were used. The extremes were naturally occurring soils from adjacent locations and were quite similar except for the salt content. The intermediate concentrations were obtained by mixing different proportions of the two original soils.

The data show a gradual decrease in crop yield with increased salt concentration. Under the conditions of this experiment, 0.4% water soluble salts was approximately the upper limit of fair crop growth. At a concentration of 1.096 salts, there was a reduction in yield of 33 to 77%. Alfalfa was more resistant to the high concentrations than oats or wheat.

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# USE OF THE BRUNTON COMPASS IN THE SASKATCHEWAN SOIL SURVEY[1]

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Various types of the surveyor's compass have long been used by geologists, foresters, topographers and survey engineers. Kellogg makes reference to the plane table compass and the forester's compass in connection with the U.S.D.A. soil surveys (1). In general, however, the surveyor's compass is rarely mentioned in soil survey literature. The Saskatchewan Soil Survey first made use of the Brunton compass or pocket transit in 1936. Since that time it has proved so useful that it is now considered an essential part of the soil surveyor's equipment. For this reason it was felt that a brief discussion of the value and use of this compass in soil mapping in Saskatchewan might be of interest to the Soils group of the C.S.T.A.

## RELATION OF COMPASS TO TYPE OF SURVEY

The soil surveys carried out in Saskatchewan prior to 1936 were chiefly of the reconnaissance and broad reconnaissance types. Sectional sheet, of the Topographical Survey of Canada, on a scale of 3 miles to 1 inchs were used as base maps. The regular pattern of sections, townships and ranges allowed the survey work to be carried on largely by north—south and east—west traverses along road allowances. Due to the large area to be covered and the broad scale of mapping, close traversing was impossible. However, the above procedure gave sufficient control for this type of survey.

In recent years the survey work has been assisted by P.F.R.A. funds, administered through the Experimental Farms Service, Ottawa. As the P.F.R.A. area in Saskatchewan was already covered by the reconnaissance soil map (*2*), it became necessary for the Soil Survey to turn its attention to more detailed surveys within the area. These include detailed reconnaissance surveys of rural municipalities, detailed surveys of proposed irrigation areas, and inspections of individual farms from the standpoint of land classification. These projects involve close traversing, particularly in the case of detailed surveys or inspections, where it is frequently necessary to outline soil areas of a few acres in extent, or to locate wind eroded pits, small depressions, houses and other important features.

In areas where suitable base maps were not available, or where there was a lack of surveyed roads, line fences and other established land boundaries, it was clearly impossible to locate soil boundaries by ordinary means. It became necessary therefore to find a method of keeping location and establishing control points on the map. It was felt that the method adopted must be reasonably accurate without being either too complicated or time-consuming. In this connection the survey staff are indebted to Mr. S.

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[1] Contribution from the Saskatchewan Soil Survey, (P.F.R.A.), University of Saskatchewan, Saskatoon, Sask. Read to the Soils Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.

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Williams of the Department of Natural Resources, Canadian Pacific Railway Company, who first demonstrated to the author the value of the prismatic compass in making land inspections.

It was finally decided that the Brunton type of compass would fulfill the necessary requirements. The wide sights and the use of the mirror permit quick and accurate sighting. In addition, this instrument is equipped with a level and scale for reading vertical angles in degrees or as percentage of slope. Hence it may be used to measure slopes as an aid to establishing topographic classes.

## IMPORTANT FEATURES OF THE COMPASS

No attempt is made here to describe the Brunton compass in detail, or to cover the practice of surveying by compass. Such information is available in the directions issued for the instrument and in various textbooks on surveying.

The instrument consists essentially of a compass to which are attached a mirror and two sights. The compass is sighted so that the object sought is reflected in the mirror. The object is correctly sighted when its image and that of the reflected sight are bisected by a hairline on the mirror.

Before commencing a survey of a given area the declination of the compass is set off by the pinion provided for the purpose, so that true north reads as zero. In some cases it is possible to secure the present declination from the engineer's survey data, but generally it is necessary to line up on section corners, or a straight fence or road.

With the declination so adjusted, all angles taken are read directly, without further correction. Bearings are also read directly, due to the fact that the E. and W. points on the circle are reversed.

The compass cannot be used very close to a car, wire fence, railway line or other metallic object. There is also the possibility of encountering local magnetic variations which result in erroneous readings. This condition occurred in one of the surveys made in Saskatchewan. The error was discovered in the course of checking the traverse against control points already established on the map. In this case the local attraction appeared to cover only a small area, and it was corrected by readings taken outside the affected area.

On windy days the oscillations of the compass needle may prevent a rapid or steady reading. In such cases best results were obtained by taking the mean of the swings, repeating the reading several times as a check. The compass has also been used on a home-made Jacob's staff, which permits more accurate sighting. This year it is proposed to mount the compass on a camera tripod where the scale of survey demands close control. With sufficient practice and care, however, it has been found that the accuracy of the compass readings is greater than that of the distances measured by speedometer or pacing.

## METHODS OF USING THE COMPASS

The Brunton compass, in conjunction with speedometer readings and pacing, has been used to carry out the following mapping operations.

1. Keeping the location of the survey party at all times.

2. Finding section corners and establishing section and quarter-section boundaries.
3. Establishing control points for secondary traverses to be conducted when making the detailed soil map. Such points include trees, houses, fence corners or any other prominent land marks.
4. Locating and mapping physical features where suitable base maps are not available. This includes the location and shape of hills, ridges, sloughs, cultivated areas, etc., also the location and direction of valleys, gullies, streams, topographic changes, etc.
5. Locating boundaries between established soil types, where these are distinguished by differences in vegetative cover, topography or elevation.
6. Determining the location of soil samples.
7. Determining the area of irregularly shaped cultivated fields or other lands.
8. Checking the accuracy of existing base maps.
9. Measuring slopes.
10. Surveying by plane table. The Brunton compass, if equipped with a special alidade protractor, may be used as a combined plane table compass and alidade.

A few examples may be given to indicate how some of the above operations are carried out. It will be obvious that at least one known point must be established on the map at the commencement of the survey. Thus the iron pin at a section corner may be used as the first station. From this point a base line such as one side of the section may be established. This is done by sighting on some object directly North, South, East or West of the pin, and driving the car toward it. The speedometer readings being kept, the half-mile or mile points may be located.

From this base line, other land boundaries may be established, while any prominent land marks may be located by graphic triangulation. This consists of sighting the object from two or more stations on the base line. The angles read are laid off on the map by the protractor, and lines are projected from each station. The intersection of the lines gives the location of the object sought.

Important features may also be located by sighting on the object from an established point, laying off a line on the map, and traversing to the object while keeping the distance by speedometer or pacing. This method is also used in the actual soil mapping operations, except that it is not necessary to proceed to the object at the end of the traverse. In fact secondary traverses are often made by sighting on prominent features located outside the project. In this way it is often possible to proceed in a variety of directions, so as to cut across soil belts and to carry out close traverses. In making traverses it is important to have a clearly defined object in view at all times.

Changes of direction are made by sighting on another object, laying off the bearing and then proceeding on the new traverse. Occasional back sights on original points serve to check the accuracy of compass readings and distances. A check on the location of the survey party may also be

made by sighting on two or more points established on the map. The readings of the bearings are reversed, as though the sights were taken from the known points. The angles given by the bearings are then marked off from each point, and the corresponding lines are drawn on the map. The intersection of the lines gives the location of the survey party.

From the main traverses shorter foot traverses may be made on lines laid off from additional compass bearings. Sloughs, ridges, hills, etc. are tied in by traversing around each feature and taking compass readings along each side. During all the operations frequent soil examinations are made and any soil features are placed on the field map at once.

## CONCLUSIONS

An attempt has been made to indicate the importance and use of the Brunton compass as an aid to soil mapping in Saskatchewan. In this connection it should be pointed out that none of the survey staff had received formal instruction in the art of surveying. Hence much of the simple technique discussed above was acquired through experience in the field. As a result, greater use is being made of the compass as skill and confidence increase.

The Brunton compass has proved most valuable in those areas where suitable base maps are not available, or where the more detailed soil maps are required. Even where large scale base maps or good aerial photographs are available, the compass may be used to good advantage in locating soil and topographic boundaries. The provision of a scale for reading vertical angles makes the instrument useful in all types of soil survey as a means of measuring slopes and classifying topography.

The compass is of particular value when used in making land inspections and soil maps of individual farms. In such cases the surveyor usually works alone. Equipped with compass, sketch book, pacing tally and a suitable tool for making soil examinations, he is able to function as an independent survey party of one.

The Brunton compass cannot take the place of the more accurate survey instruments commonly used by the engineer. Nevertheless, it has proved sufficiently accurate for the requirements of soil mapping in Saskatchewan. To the soil surveyor the lack of extreme accuracy is more than offset by the ease and speed of operation.

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# A METHOD FOR OBTAINING A COMPARATIVE RATING OF SASKATCHEWAN SOILS[1]

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The first purpose of a soil survey is to map and classify the soils of a given area. The accuracy of the mapping of soil boundaries depends upon the detail undertaken, and the latter in turn depends upon the objective of the survey and the type of agriculture to which the area is suited. A preliminary survey may have as its objective a broad generalized mapping of the soils of an area, which presupposes more detailed surveys to follow this broader mapping. Then again, while the main land use followed may be mainly extensive grain farming, local development of irrigation projects results in a much more intensive type of agriculture, and accordingly requires a much more detailed type of soil mapping.

Following the completion of the field work and the laboratory examination of soil samples, the soil map must be prepared and a report written. As a general statement it might be ventured that the soil surveyor is likely to take greater interest in the preparation of the map than in the writing of the report. Yet it is necessary that those using soil maps should frequently consult the reports if proper interpretation of the maps is to be obtained.

This neglect of the proper use of the report in studying soil survey data may arise from several causes, among which may be an uninteresting or poorly organized manner of presentation of the available material, or unwillingness on the part of the user to take the trouble to study a document which however well written and prepared must, in the main, present scientific descriptions and data about the soils of the area concerned. Kellogg (3) in his soil survey manual has given considerable attention to directions for preparing the report, with an apparent appreciation of the difficulty of making such reports usable, sufficiently informative, and yet not too voluminous.

A specific type of information which is being more urgently requested by many who are interested in the information obtainable from soil survey reports is a tabulated rating or grouping which will indicate the comparative productivity of the different soil types and phases. Such information has generally been given in one way and another in soil survey reports, but is often hidden away in the descriptions of the soils so that comparison of one soil type with another is very difficult to the layman. Furthermore, as pointed out by Morgan (4) the soil series which is commonly used as a basis for descriptive discussions in the report may have greater variation in productivity due to variation in texture than is the case between soils of different series but of the same textures.

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[1] Contribution from the Soils Department, University of Saskatchewan, Saskatoon, Sask. Read to the Soils Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.

[2] Professor of Soils.

Various writers have discussed the matter of arriving at suitable ratings or classifications (1, 2). The system of rating developed must necessarily be modified to fit the type of agriculture practised in the area concerned. It may also be modified according to the amount of statistical data relative to yields, or income, available on definite soil types, and the length of time and accuracy with which such statistics have been gathered. Furthermore, there are such factors to consider as the possibility of improving yields by fertilization, or changes in cropping system, or the deterioration of the soil by erosion, and other detrimental occurrences. Despite variations in yields on the same soil type due to managerial or other factors it appears possible to express with some degree of uniformity the comparative productive value of the soil, based on profile characteristics and chemical nature.

In the Province of Saskatchewan the demand for a rating, or grouping of soils according to their comparative productivity, has come from various Departments of the Provincial and Dominion Government, particularly those concerned more directly with land, and from Land and Loan Companies. The first definite attempt at a grouping was given in Soil Survey Report No. 8 (6) of the Maple Creek area. The grouping was a simple one indicating suitability to cropping or grazing and was included in the map legend. In Soil Survey Report No. 10 (7) which covers the greater part of the settled area of the Province, a grouping of the soils into 6 main classes is given in tabular form. The basis was suitability for wheat production and the grouping expressed the agreed opinion of those who had taken an active part in the survey. No systematic scheme of rating the soils was attempted but rather a considered judgment was given based upon all the knowledge and experience gained about the soils of the area in the course of the survey.

Within the past 3 years a demand has arisen for a more specific type of tabulated evaluation in which there would be an actual scoring of the soil, and a comparative index given for each soil type and phase. This was particularly required by the Saskatchewan Assessment Commission in attempting to arrive at new methods of assessing rural land. Accordingly an index rating based upon the system used by Storie (8) but with some modifications in detail has been worked out. The method used is outlined in the following paragraphs.

Three main factors are used. Each factor is subdivided and points allocated for each sub-factor. Points given for sub-factors are added to give the total for the main factor. The final index is obtained by multiplying the value of the three factors together.

*Factor A.* Soil Profile*

| | *Points* |
|---|---|
| (1) Texture | 40 |
| (2) Structure | 30 |
| (3) Natural fertility | 30 |
| Possible | 100 |

| *Factor B.* Topography* | *Points* |
|---|---|
| (1) Level to depressional | 10 – 80 |
| (2) Gently undulating. Slope 1–3%, frequency low[3] | 90 –100 |
| (3) Moderately undulating. Slope 3–6%, frequency low | 80 – 90 |
| (4) Very gently rolling 2–4%, frequency 4–5 | 70 – 80 |
| (5) Gently rolling. Slope 4–8%, frequency 4–5 | 60 – 70 |
| (6) Strongly undulating. Slope 6%+, frequency low | 40 – 60 |
| (7) Moderately rolling, slopes 8–14%, frequency 3–5 | 40 – 60 |
| (8) Strongly rolling, slopes 15–25% | 30 – 40 |
| (9) Hilly (over 25% slope) | 20 – 30 |
| (10) Eroded steep slopes, little vegetation | 10 |

| *Factor C.* Climate, Salinity, Stoniness, Tendency to Drift* | *Points* |
|---|---|
| (1) Interaction of soil and climate as expressed in average yield and variability of yield (see footnote 4) | 25 |
| (2) Salinity—full marks for none and deduct proportionally | 25 |
| (3) Stoniness—full marks for none and deduct proportionally | 25 |
| (4) Tendency to drift. Full marks when no drifting and deduct proportionally according to tendency for soil to be affected. | 25 |
| Possible | 100 |

[3] Frequency refers to the number of complete rolls from crest to crest in one-half mile. This is less than 2 in the case of undulating topography, but usually 4 or 5 in gently or moderately rolling phases.

[4] The climatic factor $C_1$ is from data by a student (5) working under the direction of the Department of Farm Management. Wheat yield data for the past twenty years was obtained for each municipality. The highest median yield (23 bu. per acre) was taken as 100. The standard deviation from the median yield was calculated for each municipality, and the coefficient of variability determined. The reciprocal of the lowest coefficient was taken as 100. These two factors were reduced to percentages in each case based on the municipality with the highest median yield and the one with the lowest variability, multiplied together and divided by 100 to give a single numerical value. The municipality having the highest value obtained in this way was taken as equal to 100 and values for other municipalities calculated proportionally to this to give the final index figure for climate and yield.

In order to fit this into the rating under $C_1$ it was necessary to select municipalities with fairly uniform types of soil so that the index for a particular soil type might be obtained. In most cases it was necessary to roughly interpolate in order to obtain a figure, since an example of a municipality with only one main type of soil is of rather infrequent occurrence.

The yield climatic factor index was applied approximately as follows:

| | | | |
|---|---|---|---|
| Index of 0 – 10 | 5 points | Index of 40 – 60 | 20 points |
| 10 – 20 | 10 points | 60+ | 25 points |
| 20 – 40 | 15 points | | |

*As an illustration of the above method of obtaining a comparative index number, or rating, the scoring and calculations are given for Regina heavy clay.

| Soil | Factor A (Profile) | | Factor B (Topography) | | Factor C (Various) | |
|---|---|---|---|---|---|---|
| Regina heavy clay | (1) Texture | 40 | Gently undulating | | (1) Soil climatic | 15 |
| | (2) Structure | 30 | | | (2) Salinity | 25 |
| | (3) Nat. fert. | 30 | | | (3) Stoniness | 25 |
| | | | | | (4) Tend. to drift | 17 |
| | | 100 | | 100 | | 82 |

$$A \times B \times C = 82$$

Regina heavy clay is a lacustrine soil of the dark brown soil zone. It is excellent land for large scale wheat production. The texture is heavy, structure good, and the natural fertility high. The topography of typical undulating areas allows sufficient drainage, and high arability. The average yield is good, but the variability is moderately great. It is free of "alkali" and also of stones. It drifts readily but on account of the depth of profile is not seriously affected as far as productivity of the soil is concerned. All soil types mapped in the Province have been rated by the method illustrated above.

*Point of Non-arability*

It is obviously impossible to declare definitely where the line between arable and non-arable soils should be drawn. For the present, and with regard to past performance of these lands, an index value of 30 is suggested as being indicative of the point of marginality.

This index rating is based on ability to produce grain, more particularly wheat. It is an attempt to express soil factors in a single numerical value which will allow comparison between various soils. The final results, as must needs be, are tempered by the experience and judgment of the men who have been active on soil survey work, and with consideration of the data secured over many years by the Farm Management studies in Saskatchewan.

It is not considered that this is a final judgment on each soil's productive capacity since diversification of farm practice, now appearing on many soils, will inevitably modify some of the conditions relating to productivity. However, the greater weight in the factors used is given to the physical and chemical characteristics of the soil profile and to physical features of the land. Such factors have some degree of stability.

The first use to which this index is being put is in the reassessment of rural municipalities in Saskatchewan. It is being used in the latter case as a basis for a "natural" land classification and for comparison between soil types. Superimposed on this is a "practical" classification to include such factors as freight rate costs, distance from market, etc. It should be pointed out that land inspectors, assessors, or others who may use such a rating must have sufficient training and experience so that they are able to recognize the soil types and phases encountered on parcels of land being inspected, especially in localities where mapping is incomplete, or where only broader reconnaissance types of soil maps are available.

## ACKNOWLEDGMENT

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# SOIL SURVEYS IN RELATION TO LAND CLASSIFICATION IN ALBERTA[1]

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During the past few years land classification and its aim, land use planning, has been receiving more and more of the attention of the nation as individuals and as a group. The reason for this is, in the words of Robert M. Salter speaking at the 29th annual meeting of the American Society of Agronomy held in November 1936:

"The land use movement is the child of agricultural distress. In the post war years when agriculture was lagging farther and farther behind industry there grew in the minds of many the conviction that the ills of agriculture were not alone the result of external maladjustments, but that agriculture was really suffering internally as well, and that one need regardless of what else was a new land use policy in America befitting its maturity. After the depression struck and agriculture had begun its precipitous decline towards the economic cellar, it appeared that the time for action had arrived."

The land policy in effect in the Canadian West was one whose principal aim was to transfer lands from government or private company ownership to the hands of the settler with little regard to the land's potential productivity. This policy has caused one of the main maladjustments from which western agriculture to-day suffers—namely, a haphazard growth that has resulted in, among other things:

(1) Settlement in areas unsuited to the type of agriculture practised on them, or in areas where the provision of social services placed too great a tax burden on either the individual holdings in the area or on the nation as a whole.

(2) Wrong use of the natural land types that leads either to the impoverishment of the land or of the farmer, or more often both.

(3) The acquisition of land parcels of a size inadequate to provide a decent standard of living to the operator.

These in turn result in such things as tax delinquency, relief, deserted homes, soil deterioration, etc.

It is not the intention, nor is it just, to criticize any individual or group for this state of affairs. In some places the clouds have been on the horizon for a long time. For example, water erosion in the United States has been recognized for over a hundred years; widespread national control by the federal government has been taken within the last decade. But most of the mistakes could not have been foreseen; particularly is this true of conditions on the Great Plains of North America. The general aim to-day is for a more constructive policy of land use planning. This requires the efforts of other workers as well as the pedologist. He is chiefly

[1] Contribution from the University of Alberta, Edmonton, Alta. Read to the Soils Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.

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concerned in: (1) Chemical, physical and biological research, and (2) soil survey and land classification, but these soil data are necessarily the starting point for any such planning and in one respect or another all the work done by the pedologist is directed towards land use planning which is, to give a simple definition, "to find a pattern or use that will best serve each acre of land."

Following the above hypothesis the Alberta Soil Survey has prepared a land class map to accompany the soil map. This map interprets the physical data of the soil map in terms of productive ability. Economic data such as distance from transportation facilities, price and price fluctuations, cost of the articles of production, etc., are given no direct consideration in this evaluation. It should be stated, however, that certain economic factors, for example price, have in a national way influenced the kind of crops grown in the past, the record of which is used as a measuring stick of probable productivity. This map provides for 3 pasture classes, 1 marginal arable class and 4 arable classes. It is also recognized that the development of new varieties of crops, changes in farm practice or changes in demand relationships might render some lands economically more or less profitable to farm.

As stated earlier the land class map accompanies the soil map; the soil map is the permanent map, or it might be called the basic map. The system of soil classification used on the soil maps by the Alberta Soil Survey is being evolved to meet the classification problems as they are encountered in the field by that survey. Since the physical factors that find expression on the soil map in designating or differentiating soil areas are the ones which determine the land class rating given to an area, a brief description of that system is given below.

Each soil area on the map carries, besides the surface texture class, a three digit number. These digits refer respectively to the soil colour zone, the mode of deposition of the parent material and to the type of soil profile formed on this parent material. In addition to these, notes on such things as stoniness, topography, surface erosion, and cultivation are taken in the field, and with the exception of cultivation these factors are either expressed on the map or influence the final designation given to a soil area. This classification system has as its aim the recognition and expression of the principal differentiating factors in soils and should, if and when found necessary, be easily related to other series classifications.

The following texture classes are used: sand, sandy loam, fine sandy loam, very fine sandy loam, loam (light, medium and heavy), silt loam, clay loam, silty clay loam, and clay. In general these classes have an increasing percentage of silt plus clay in the order given; that is each is slightly heavier than the preceding class. These classes differ in chemical and physical properties and therefore differ in productivity and in utilization.

The first or hundred digit number used refers to the soil colour or zone in the following order:

1. *Brown Soils*

These soils are distinctly brown in colour. The nitrogen content of the A horizon ranges from about 0.10 to 0.20%; the average nitrogen content of the surface foot is about 0.13%. They have developed under a rainfall

averaging about 12 inches annually. This zone is subject to great rainfall fluctuations; for example, at Medicine Hat, Alberta, during the last 35 years the annual precipitation has fallen as low as 6 inches and gone as high as 25 inches. Such variability in the rainfall distribution must be reckoned with in any productivity rating. The selection of crops that can profitably be grown in this zone is distinctly limited. Because of the limited rainfall in this zone, only the best soil types are considered as arable lands, and these are principally wheat growing areas.

2. *Dark Brown Soils*

These soils are dark brown when cultivated and they may have, in the virgin state, a thin black layer on the top. The nitrogen content of the A horizon ranges from about 0.15 to 0.35%; the average nitrogen content of the surface foot is slightly over 0.20%. They have developed under a rainfall of about 15 inches annually. Although rainfall is also a limiting factor in crop production here, drought years do not come as frequently as in the brown zone. Very good wheat lands occur in this zone. In this and in the brown zone the heavy textured soils are the most consistent producers.

3. *Shallow or Southern Black*

These soils are black in the cultivated field but the black horizon is only 6 or 8 inches deep. The average nitrogen content of the A horizon ranges from 0.25 to 0.40%: the average nitrogen content of the surface foot is slightly over 0.25%. In southern Alberta they have developed under a rainfall of 18 to 20 inches but with a high rate of evaporation. In the east central portion of the province some shallow black soil may be found. In this section the rainfall is midway between that of the dark brown and black zones. Although principally a wheat growing area this zone allows for more diversification than the two previously mentioned ones.

4. *Black*

In these soils the black layer averages a foot in depth, and the lime horizon is much deeper than in the shallow black. They have developed under a rainfall generally no higher, and sometimes not as high, as that of the shallow black soils but with a much lower evaporation rate. The average nitrogen content of the A horizon ranges from 0.40 to 0.70%: the average nitrogen content of the surface foot is about 0.50%. Due to more favourable climatic conditions a much greater number of soil types is considered arable than, for example, is the case in the brown soil zone.

SUMMARY OF NITROGEN CONTENT OF SOILS FROM VARIOUS ZONES

| Zone | Average depth of A horizon | Range in nitrogen in A horizon | Average nitrogen in surface foot |
|---|---|---|---|
| | inches | % | % |
| Brown | 5 | 0.10 to 0.20 | 0.13 |
| Dark Brown | 6 | 0.15 to 0.35 | 0.20+ |
| Shallow Black | 7+ | 0.25 to 0.40 | 0.25+ |
| Black | 10+ | 0.40 to 0.70 | 0.50 |

The present survey conducted under the P.F.R.A. has not done any work in the wooded section of the province and therefore no classification allotments, as yet, have been made for these soils. However, the Department of Soils at the University of Alberta used a zone number for these soils in the St. Ann Soil Survey bulletin No. 20. In the northern surveys, conducted by this department prior to 1932 the terms $W_1$, $W_2$, and $W_3$ were used to separate the wooded soils on the degree of podsolization, these separations having a distinct utilization application.

In general the colour number will follow the zone belts, but there are cases where islands of darker or lighter soils may occur within any soil zone.

The second, or tens digit, refers to the method of deposition of the parent material in the following order:

0. *Residual Soils.* These soils are formed *in situ* from the weathering of the underlying bed rock. They are generally stone free and in fairly level topography.
1. *Sorted Residual Soils.* These soils are formed principally from the weathered material of the underlying parent rock, but this material has undergone some surface sorting. Many of these soils have been glaciated but the till has all been eroded off leaving only the transported erratics on the surface.
2. *Glacial Soils, unsorted and variable.* These areas are typically moraines. Stones are found throughout the profile. There is generally considerable variation in texture and profile. Sloughs and meadows often dot the area.
3. *Resorted or Uniform Glacial Soils.* These soils are usually formed on ground moraine. The surface till has had some water sorting and possibly a little deposition covers the area. The profile is fairly free of stones, particularly in the surface horizons; the texture and profile is quite uniform throughout the area and in general there is a "cleanness" to the profile and area that is not found in the glacial dumps, that is in the soils of group 2.
4. *A grouping called Gravelly Outwash.* These are very gravelly and stony soils formed either by washing out of the finer materials from glacial dumps or from alluvial deposition.
5. *Alluvial Soils.* These soils are characterized by water worn stones in the profile and by the presence of sand and gravel lenses throughout the profile. The texture of the surface soil may be quite variable.
6. *Alluvial or Aeolian Soils.* In this class are the fairly uniformly deposited soils, usually light to medium textured. They are relatively stone free.
7. *Aeolian or Lacustrine Soils.* In this class are put the uniformly deposited soils, usually medium to heavy textured. They are relatively stone free.

In cases where one mode of deposition lies over another relatively close to the surface, a fraction in the tens column is used.

The third or units digit refers to the profile development in the following order:

0. These soils have little or no profile development and very little horizon differentiation. Sands, many sandy loam soils, recently flooded river bottoms, and badly drifted areas, may carry the 0 profile designation.

1. These are hillside soils. They are locally more arid than the normal soils and because of this, as well as erosion, they are generally of a lighter colour and have a shallower profile than the normal soils.

2. These soils are non-saline and have a profile normal for their texture and the climate of the area. They generally have a cloddy to columnar $B_1$ horizon.

3. These soils are non-saline but are developed in areas of low position and as a result they are locally more humid than the surrounding normal soils. The profile that develops is deeper and darker than the profile normal for the area.

4. These soils are characterized by a weak solonetz development. The $B_1$ is quite waxy and hard, but the hard round top of the solonetz-solod is absent.

5. These soils are saline and the profile generally shows evidence of restricted drainage.

6. These soils are slightly saline. They have a hard impervious $B_1$ horizon and generally a light leached $A_2$. The $B_1$ horizon is capped by hard white rounded tops. Areas of these soils, particularly in the brown soil zone, have a patchy microrelief due to the erosion of the A horizon.

7. These soils have a high lime content. The lime concentration is found to the surface of the A horizon.

Fractions used in the units column indicate a profile complex.

It will be noted that there is no place allotted for parent material. Where differences in this occur they are described in the report that accompanies the map. In a general way, however, these differences find expression through some of the factors that are expressed in the series designation.

Each of the factors described above that finds expression on the soil map definitely affects the probable productivity of a soil area. Therefore in compiling the land class map each physical factor is given a percentage rating, the most desirable rating in each case being 100%. These percentage ratings were multiplied together to obtain the final percentage rating of the soil area. It was thought that the various percentages should be multiplied rather than added together; in this way any one detrimental factor that would seriously affect crop production would get true expression in the final rating.

Following this, certain groupings had to be made of the ratings so obtained. It was found that the range for one group increased in size from the poorer classes to the better classes; for example, the product of the multiplied factors in the poor to fair pasture areas would fall between 0 and 5 whereas for the very good to excellent arable areas, the product would fall between 80 and 100. The change in the size of the range increased in a logarithmic-like manner, and land that was marginal, that is between arable and pasture, would have a rating that fell somewhere around 20

to 30. The following example from the Neutral Hills area will illustrate the use of this formula:

| | |
|---|---|
| Colour (rainfall, fertility) | 50—Brown to dark brown |
| Deposition | 80—Glacial |
| Profile | 100—Normal |
| Texture | 70—Light Loam |
| Alkali | 100—Absent |
| Stones | 60—Quite numerous |
| Topography | 40—Very hilly. |

These multiplied together give a rating of 7 and this would fall in the group—fair to fairly good pasture.

Although no definite production values can be placed on the various groups, the following figures give an approximate value of the main groups that appear on the classification map:

Class 1: Poor to fair pasture—takes over 40 acres annually to pasture one head of cattle.

Class 2: Fairly good to good pasture—takes between 20 and 40 acres per head.

Class 3.: Good to excellent pasture—takes under 20 acres per head.

Class 4: Marginal arable land has produced about 10 bushels of wheat per acre.

Class 5: Fair to fairly good arable land has produced about 12 to 15 bushels of wheat per acre.

Class 6: Fairly good to good arable land has produced about 15 to 20 bushels of wheat per acre.

Class 7: Good to very good arable land has produced about 20 to 25 bushels of wheat per acre.

Class 8: Excellent arable land has produced over 25 bushels of wheat per acre.

These yield averages have been obtained from government statistics, farmers and ranchers in the surveyed areas, and from the records of the P.F.R.A. economic survey.

It is realized that we are not doing anything new in this work. The method outlined above is an effort to meet present day requirements by taking an inventory of our soil resources and interpreting the data in terms of a probable productivity classification. This information should be of material aid in any programme of land use planning.

This paper is in the nature of a progress report of the Alberta soil survey, P.F.R.A. The classification methods briefly outlined in this paper are being added to as needed to meet classification problems encountered in the field. These methods have been evolved by Mr. Wm. Odynsky[3] and the author under the direction of Dr. F. A. Wyatt[4] and with assistance, also, from Dr. J. D. Newton[4].

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# DIFFERENTIATION OF FOREST AND AGRICULTURAL LANDS[1]

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Forestry and Agriculture, providing in British Columbia a combined annual income of approximately $120,000,000, represent two important basic industries which are closely related in so far at least as land use is concerned. It has been said that "Forestry begins where Agriculture ends" but it is undoubtedly true that the latter has on occasions gone too far, due in part at least to lack of direction in the use of logged-off lands. Herein, perhaps, lie some of our present-day difficulties. Planning for use based on a study not only of the soil itself but also the various factors contributing to its producing power should reduce waste effort and financial loss.

Soil survey is primarily concerned with mapping of soil types whereas a land use study involves a determination of the most effective use to which the various soils may be put. Thus, in the differentiation of forest and agricultural soils, soil survey is essential, but in addition many other factors must be given due consideration. Among these one might mention climate, also whether or not an area of good agricultural land in a typically forest region is of sufficient size to constitute an economic unit and whether or not it is readily accessible. There appears to be good reason for suggesting the consideration of another point, which in British Columbia is being largely overlooked, namely, the influence of forest growth on moisture movement and soil moisture supply. It is this aspect, as a factor in determining effective land use, to which the writer wishes particularly to call attention at this time.

That forest cover influences ground water supplies and rate of run-off appears perfectly logical and yet there is a scarcity of precise experimental data in support of the belief. This is to be expected in view of the complexity of such a study. Early in the present century Engler (4) of Switzerland devoted 12 years to a study of the influence of forests upon stream flow but his results lacked exactness due to the fact that his data were taken from two watersheds in their natural conditions, one being wholly forested (97%) and the other only to a small degree (35%). The only comprehensive study known to the writer is that by Bates and Henry (1). After an extended search these workers finally selected for their study two watersheds, A and B, described as follows:

| | *A* | *B* |
|---|---|---|
| Total area | 222.5 ac. | 200.4 ac. |
| Extreme length | 7300 ft. | 4600 ft. |
| Mean width | 1328 ft. | 1898 ft. |
| Elevation | 9373–11,355 ft. | 9245–10,952 ft. |

[1] Contribution from the Soils Section, Department of Agronomy, University of British Columbia, Vancouver, B.C.

Read to the Soils Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.

[2] Professor of Agronomy.

These areas were alike in geological origin and mode of formation. They were similar in soil texture and both had essentially the same climate and almost identical ground cover.

Weather and stream flow records were taken on both watersheds over and 8-year period, then B was completely denuded and records continued for an additional 7 years. During these periods the annual precipitation figures were:

| | *A* | *B* |
|---|---|---|
| Pre-denudation period | 21.03 in. | 21.10 in. |
| Post-denudation period | 21.16 in. | 20.83 in. |

During the pre-denudation period the average annual discharge of A watershed was 6.08 inches and of B, 6.18 inches, either amount being in round numbers 29% of the average precipitation. During the post-denudation period the annual discharge by A was 6.21 inches, or again 29% of the A precipitation while that of B was 7.26 inches or 35% of the B precipitation. The flood run-off from B prior to denuding was the same as that of A, but upon denuding it was much more marked. For instance, the peak of flood run-off which occurred in the third year was 35% in excess of that from A. This excess diminished until the end of the experiment when it was 22% greater. It might be recalled at this point that a feeble growth of aspen 4 feet high had developed on the watershed upon the conclusion of the experiment.

It is admitted that no data based on carefully controlled experiments comparable to those of Bates and Henry are available in British Columbia, but many observations from unrelated districts are sufficient to lead one to the definite conclusion that the removal of forests, clearing and draining of land on the higher levels are in certain instances having a detrimental effect on many fertile agricultural lands. The evidence as it presents itself lends strong support for the belief that in the not too distant future the effect of unrestricted logging and clearing will constitute a major problem in many areas.

Three possible aspects of this problem present themselves:

1. Flooding of bottom lands due to the rapid run-off aggravated in part at least by the denuding and clearing of the watershed.
2. Clearing and draining of the high lying lands with a possible consequent reduction of ground water in the soils of the lower benches.
3. Erosion of the watershed.

In regard to the first point it must be admitted that occasional flooding of bottom lands has always been a problem, but there appears to be little doubt that in many localities it is becoming more acute with the passage of time. In the Cloverdale watershed, for instance, there are approximately 62,000 acres of which 12,000 acres are bottom land subject to flooding. It is stated on good authority that years ago before the upper reaches of the watershed were cleared and drained to any appreciable extent, 36–48 hours were required following a heavy rain before any perceptible rise in water appeared on the low land; now it occurs almost immediately and the peak is much higher. Thus it is maintained that during recent years, flooding, such as was never known during the early years of settlement, has occurred.

Silting-in of the drainage basin probably aggravates the situation but is not sufficient to explain the acuteness of it. Farmers who are perfectly familiar with the Cloverdale region report that, prior to clearing of land adjacent to Bear Creek, water supplies were maintained throughout the year in the upper reaches of the creek where now the creek is dry for a considerable portion of the year. Similarly many of the light textured soils in the area which were once reasonably well supplied with moisture even during the summer season are now subject to serious drought.

Hatzic Prairie is another district which is subject to severe flooding during the peak run-off season. Detailed data are not available but the flooding appeared to become more pronounced subsequent to logging of the watershed. During recent years flooding has become still more serious but this aggravated condition is undoubtedly due to eroded material filling in the drainage basin. Needless to say the occupants of the fertile bottom lands throughout this area are finding themselves in a rather serious situation.

The second aspect, concerned with the lowering of ground water levels on bench lands, introduces a different type of problem. The denuding, clearing and draining of lands at high elevations facilitate the escape of surface water, thereby eliminating it as a possible source of ground water for sub-irrigation and well-water supplies at lower levels. Whether or not this has any appreciable effect on ground water supplies at any point is difficult to prove experimentally but already farmers in some districts are deeply concerned about it. One farmer, for instance, reports a drop of several feet in the height of water in his well during the past 7 years. Similar observations have been reported from the United States. Brown (2), for instance, states that in some localities "the water table has been lowered beyond the level of efficiency" through removal of surface cover as in excessive deforestation and extensive cultivation. It has in fact been roughly estimated that over large areas in the United States the water table has been lowered from 10 to 40 feet by these methods.

The third aspect, namely, erosion, is not as yet considered to be a serious problem in British Columbia in so far at least as agricultural lands are concerned, but the filling in of drainage basins by eroded material from logged-off lands is militating against flood control on low-lying lands in some localities. As watersheds are cleared of forest growth the harmful effects of erosion will doubtless become more pronounced. In the work of Bates and Henry to which reference has already been made, erosion from B watershed prior to denudation was 80% of that from A, but during the subsequent period erosion from B was 7 times greater than from A. During the year of greatest erosion the detritis from B was 14 times grearer than that from A while the latter varied only very slightly from its normal. It is only fair to point out that the amount of material actually eroded during this experiment was relatively small due to the course open nature of the soil, but the percentages are rather striking. Corresponding losses from a fine textured soil may be cited, by way of example, where during a storm in the Northern Mississippi area land under forest cover lost 75 pounds of soil per acre, while adjacent land under cultivation lost 68,000 pounds per acre. It is not to be asssumed, therefore, that all land subject to erosion should be retained for forestry purposes, but, where soils are sub-marginal

and where erosion cannot be otherwise controlled, every effort should be made to retain a forest cover during logging operations and subsequent thereto in order to protect the soil mantle. Examples may be readily cited of mountainsides or hillsides, which once carried a stand of merchantable timber, but which are now absolutely devoid of soil due to erosion.

Problems relative to flooding and drought will undoubtedly increase as forestry gives way to agriculture and may or may not be due to the misuse of land. In any event, now, while the major forest areas are being determined, appears to be the time to give serious thought to moisture conservation as effected by forest cover on adjacent areas. Consideration might well be given to the protection of natural water reservoirs at elevation, which protection may conceivably increase the moisture supply on the lower benches, and, at the same time, reduce the tendency for flooding on bottom lands. Such protection might be provided through reserving such areas for forestry purposes.

Other regions again are already more or less completely denuded of tree growth and have been, or are being, subjected to indiscriminate clearing regardless of the character of the soil. Undoubtedly the most practical method of reconstruction is the elimination from agricultural use of the poor lands which even in good times cannot show a profit. Reference to the Fraser Valley Soil Survey Map will disclose a number of soil types. Everett loamy sand for instance is in the writer's opinion sub-marginal for general agriculture and should have been reserved for forestry purposes. Again, on many farms throughout the Fraser Valley, and elsewhere as well, where the soils are predominently agricultural, small acreages are to be found which are of relatively little value for agriculture but would have made excellent fuel and timber lots for local use. Their value too for the production of small trees for the Christmas trade should not be overlooked. It is the writer's considered opinion that reforesting of many of these poor soils, while involving an expenditure of time and money, would ultimately return a profit because the land would once again be productive. Such would enable the farmer to become more self-sustaining and would provide an extra labour activity during the slack season on the farm. It is conceivable, too, that these reforested areas might have an appreciable influence on moisture supply of adjacent agricultural areas. Bourne (3) of Oxford University is responsible for the statement that "reafforestation would certainly help to conserve the water supply and prevent rapid run-off".

Any land use policy which will assist our upland glacial soils in withstanding summer drought is worthy of careful consideration. One might think that with an annual precipitation of 35–70 inches, lack of moisture could scarcely be a problem, but due to lack of summer rainfall and low moisture-holding capacity of many of these soils, moisture conservation is a factor of major consequence. This may be more fully appreciated when one recalls that it is impossible to maintain good pasturage on many of these soils throughout the season, and summer seeding of any crop is rarely attended with even moderate success. The accompanying chart which represents average precipitation at 4 stations over a period of 11 to 40 years, shows clearly that summer precipitation is distinctly low. Assuming that 3 inches of rain per month are required for optimum growth one can appreciate the amount of storage that is required if the crop is not to suffer.

The markedly low storage capacity of many of these soils accentuates the drought problem.

In discussing land policy Bourne has stated that "agricultural and forest policies should be complementary and in no sense antagonistic". We, as technical agriculturists and farmers in this Province, might well adopt a modified form of this statement as a creed for our guidance—Agriculture and Forestry should and must be complementary for optimum return.

## CONCLUSION

Accessibility and the character of a soil as disclosed by a general soil survey are basic principles underlying the establishment of boundaries between forest and agricultural areas. However, before such boundaries may be set forth, topography, as related to watersheds and natural drainage basins, should and must receive the most careful scrutiny in order to minimize erosion and to insure most efficient use of surface and ground waters. To accomplish this end active and sincere co-operation on the part of the specialists in the fields of Forestry and Agriculture is essential and, in some instances, services of specialists in the Provincial Water Rights Branch might well be invaluable. Serious consideration given to land use at this time as between Forestry and Agriculture should pay handsome returns for future generations.

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# A METHOD FOR TAKING SOIL MONOLITHS[1]

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Soil monoliths for use in the laboratory, classroom or office are a means of presenting, recording and comparing many different profiles. Satisfactory monoliths, however, are not always easily obtained.

## REVIEW OF PREVIOUS METHODS

*Use of Cements and Adhesives*

Many of the methods involve the use of cementing agents to bind the soil particles to a base. Bushnell (1) uses a hot pad glue to attach a canvas backing to the soil profile. After drying, the canvas with the adhering soil is broken away and fastened to a board for permanent support. A somewhat similar method is used by Schlacht (3, 5) in which a special lacquer, a condensation product of urea and formaldehyde, is used to cement the soil particles together. When this has set, a celluloid strip is attached to the prepared soil surface and the cemented profile broken away and fastened in a wooden box. The same lacquer is used for cementing in all three stages. Morwick (4) uses sodium silicate diluted with three parts of water as a cementing agent. This is sprayed on the soil surface and allowed to set for 24 hours. A board is attached with hot tar to the prepared surface. The profile is then cut away and two inch wooden sides added. Harper (3) tried many different types of adhesive compounds and finally recommended a mixture of one part clear lacquer to two parts of lacquer thinner, for use in binding the soil particles together. The cemented surface is attached to a board with asphalt or coal tar pitch.

These methods require two days to complete the operation. They are rather messy in that they require sprayers or brushes, a blow torch or other heating apparatus and adhesive materials. With single grained or incoherent soils they are unsatisfactory unless the soil particles are previously cemented. The moisture content of the soil is also a factor influencing the use of these methods.

*Use of Wood and Metal Forms*

A second system of taking monoliths involves the use of boxes. One method is to carve out a monolithic soil profile so that a box may be fitted over it. The monolith and box are then broken from the soil mass. The weakness of this method is that many soils are too stony or incoherent to be satisfactorily carved prior to boxing. The Bureau of Soils of the United States Department of Agriculture as reported by Harper (3) propose a wooden box which has only three sides and is lined with galvanized iron. Special steel cutting edges are temporarily attached to the sides and the box is forced into the vertical soil section by means of a jack. A cover is placed on the profile before it is removed. In the laboratory the monolith

[1] Contribution from the British Columbia Forest Service, Department of Lands, Victoria, B.C.

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is kept moist by placing damp sphagnum moss beneath the soil and a glass cover installed to prevent evaporation. Chapman (2) suggests using a galvanized iron trough, forced into a nine inch hole dug with a post auger. By this method one cannot tell if the profile is typical until after the monolith is removed. Harper (3) also suggests the use of a metal trough forced into the soil section. The monolith, however, is obtained by transferring this profile to a board after treatment with lacquer.

## DESCRIPTION OF METHOD

### *Construction of Form*

The method to be described in this paper belongs to the second group reviewed. The monolith is taken in an easily constructed trough. It is made by attaching a strip of 22 gauge galvanized iron 2 inches wide to a board 36 × 4 × 1 inch, so as to form an open ended trough in which the metal sides project 1 inch beyond the open end. These dimensions have proved sufficient locally; they may however, be increased or decreased as desired.

In constructing the trough the sides must lie flush with the bottom of the board; otherwise they will be wavy and flexible instead of straight and rigid. For this reason it is best to start with the centre nail at the bottom end, then bend one side, pulling it taut with a pair of pliers and partially drive in a second nail near the open end. Repeat with the other side. When the sides are straight and flush, drive in intermediate nails 4 inches apart. Three-quarter inch roofing nails have proved quite satisfactory in practise.

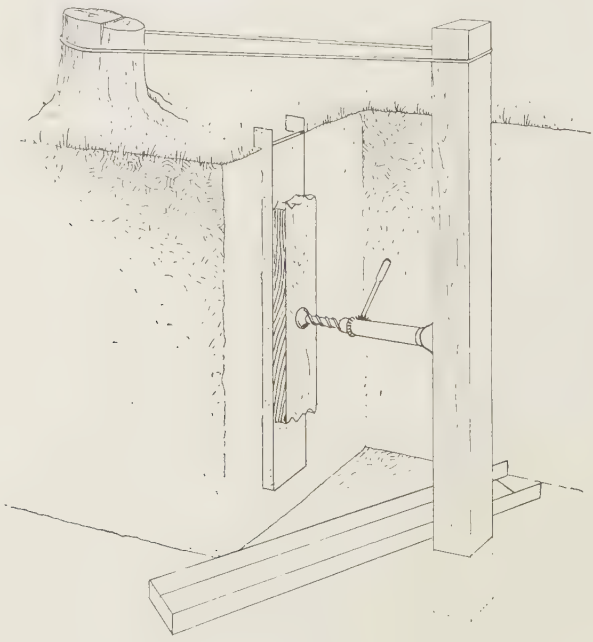

FIGURE 1. Trough and jack in position for taking soil monolith.

*Taking the Monolith*

The monolith is most easily taken in a road cut, though a pit 4 feet deep, 3 feet wide and 3 feet long is satisfactory.

After facing off the exposed soil, the metal sided trough is forced into the soil section by means of a car jack of the axle type, as shown in Figure 1.

The trough is placed so that the top of the board is level with the top of the litter layer when it is gently compressed. The metal sides then project one inch above the surface. A piece of 2 × 4 is placed behind the trough as a temporary brace, giving additional rigidity to the trough and ensuring an equal distribution of pressure from the jack. The foundation for the base of the jack must also be strong. An old fence post embedded in the soil and snubbed to an anchor by a piece of strong wire works well.

In forcing the trough into the soil, care must be taken to see that it goes in evenly. Keep the soil continually scraped away from the sides and watch for stones or roots obstructing progress. Cut any roots flush with the metal sides and manipulate any interfering stone so that it comes just in or outside of the metal.

Once the trough is forced completely into the soil, bend the projecting sides firmly over the top of the litter layer. Cut all surface roots from the top with a sharp spade, then cut the soil well back from the sides. Make sure that the deeper roots are severed. This may be done by passing a knife blade over the face or front of the trough. Remove the jack and with both hands grasping the soil column, tip the monolith back to an angle of 45 degrees and lift it out.

Very sandy soils have a tendency to slip out of the bottom of the trough, or to buckle in the middle. This may be overcome by encircling the soil and trough with one or two bandages before removing the jack.

FIGURE 2. Soil monolith and trough. Note litter layer, roots and stones.

The tendency to slip may be stopped by fastening a small bracket across the centre of the trough. If the bracket is not more than half an inch deep it will be hidden in the back of the finished monolith.

## DISCUSSION

Successful monoliths have been taken of heavy textured clays, incoherent loamy sands and moderately stony soils by this method.

In considering the merits of the method the following points should be considered:

1. The cost of the material in the trough is about 25 cents. It is easily and quickly constructed.
2. The whole operation of taking the monolith requires from 1 to 3 hours. It can be done by one man, though two are better.
3. The soil surface requires no previous treatment, thus the structure and consistence are natural.
4. The monolith is cut by the metal sides ensuring an exact fit between the sides and the soil column.
5. The open top with the projecting sides enables the litter layer to be taken undisturbed.
6. The projecting sides provide an adjustable height, so that when pressed down, the soil column is snugly enclosed.
7. The monolith remains permanently in the original trough, thus all the profile characteristics such as horizons, structure, distribution of stones and roots, etc. are preserved unaltered.

## SUMMARY

A method is described whereby soil monoliths are obtained in a natural state, without the use of cementing materials. The essential feature is a trough with galvanized iron sides, open at one end. The sides project beyond the open end. The trough is forced into the exposed soil section by means of a jack. The projecting sides are then bent over the top of the monolith. The soil horizons including the loose litter layer are thus securely yet naturally preserved.

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# THE NATURE OF SOIL PARENT MATERIALS IN SOUTHERN BRITISH COLUMBIA[1]

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Climatic and biological activities have been operative over the mountainous surface of southern British Columbia since the decay of glaciation, and the solum has an average depth of only 18 or 20 inches. Because of the shallow solum the texture and other features of the relatively undisturbed parent material which underlies the weathered surface often play an important role in land use.

In order to classify the soils of this region it was necessary to study the geological forces that governed the grinding, sorting and distribution of the soil-forming parent materials, this feature being reflected mainly in the composition of the parent materials and in the texture of the whole soil profile. Because of glacial pulverization of a variety of rock formations, parent materials are composed of a general mixture of these mineral constituents, textural grading having occurred both during outwash from the melting ice-sheet and during the subsequent erosion cycle which is still in progress.

## ORIGIN OF PARENT MATERIAL

In Pleistocene time glacier ice covered the greater part of the Province, the upper limit of glaciation in some cases extending to an elevation of about 7,000 feet. Only the highest peaks were left exposed, and today these unglaciated summits present an angular appearance against the sky, in contrast to the rounded tops of those at lower elevations.

During this prolonged period of glaciation at least one important recession of the ice-front occurred along the south Pacific Coast. This recession was of sufficient duration to leave extensive soil-forming deposits in a narrow strip along the east shore of Vancouver Island (2) and to allow vegetation to invade the delta of the Fraser River (1). Evidence of a similar interval of ice retreat and subsequent advance in the interior of British Columbia has not been established.

The movement of glacier ice in every part of the Province had the general effect of scraping up the soils inherited from the Tertiary and of mixing this material with new debris of all textures derived from the abrasion of many kinds of rock formations. An important feature of the mixing process was the inclusion of large supplies of calcium and other essential elements in the general agglomeration of materials.

The final stage was one of ice decay and retreat from the lower to the higher elevations. During general deglaciation of a rugged terrain the mixture of old Tertiary soils and new rock debris was released from the ice and at least partly exposed to the sorting action of fast running streams, which deposited their loads in the valley depressions.

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[1] Contribution from the Soil Survey Department, British Columbia Department of Agriculture, Victoria, B.C. Read to the Soils Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.

[2] Officer-in-charge.

At this time the troughs of the main valleys of the interior were partly ice filled, thus forming effective dams against which the waters of numerous lakes were impounded at elevations from one hundred to several hundred feet higher than the level of present runoff. Into these lakes the debris from the ice sheet was discharged by rejuvenated streams during the summer melting period.

The loads of streams varied in texture from coarse gravel to fine clay, and water sorting occurred where the streams entered the glacial lakes. Gravel was deposited at the mouths of the more vigourous streams, followed in order by separate deposits of sands, silts and clays. The glacial lakes disappeared on melting of the ice-dams, and these water-sorted materials were left exposed as a series of valley-filling deposits. The gravels and sands now form a succession of terraces where tributary streams enter the main valleys, while the silts and clays occupy the former lake bottoms.

During glacial decay an oscillation of the land in relation to the sea occurred at the mouth of the Fraser River. The whole delta was submerged and its position was comparable, as a repository of fine sediments, to the glacial lakes of the interior. The coarse materials built up terraces in the Fraser Canyon; while a comparatively small amount of fine sediment covered the submerged Vashon Till (4) and pre-existing sands and gravels, spreading beyond their limits to form a fine-textured delta deposit. Soils developed on this material have been named Alderwood, Lynden and Whatcom series (6).

*Interglacial Deposits on Vancouver Island*

In the spring of 1939 an area covering about 21,000 acres between Campbell River and Menzie's Bay on Vancouver Island was surveyed, and it was found that in relation to one another the soil-forming deposits of this district differ remarkably from any valley-filling accumulations yet found in the interior. The inland deposits of the glacial lake stage take the general form of a whole series of textural separates referable to the same period of runoff, spreading fan-like from the mouths of tributary streams; while those at Campbell River occur as three distinct layers, resting on top of one another according to age. All three of these layers are exposed to a greater or less extent on the surface, due either to erosion or to incomplete covering of the lower layers by the upper ones during deposition, and each has developed an individual soil profile with its own textural and other characters. The fine textured middle member of the group is of most agricultural value under coast climatic conditions, but unfortunately exposures of this type are less extensive than those of the coarser upper and lower layers.

The lowest deposit is a thick, hard, cemented boulder clay which lies on bedrock and on stratified gravels. This is known as the Admiralty Till, (4), referable to the decay of the first ice-sheet. On exposure it develops a stony, sandy loam solum about 2 feet thick, beneath which the boulder clay remains almost as hard as concrete, being impervious to roots and water.

Lying directly on the boulder clay in other parts of this area is a stratified sediment composed of layers of fine sands, silts and clays, the thickness of this deposit varying from a few feet to 40 feet or more. The occasional

presence of clam shells denotes its marine origin, and it is probably a part of the Maywood formation studied by Clapp in the vicinity of Victoria (3). The solum weathered from this material is about 20 inches thick and has a loam texture in the mapped area, but owing to its mode of formation as delta mud flats of creeks, the texture may vary from fine sandy loam to clay. Fine texture is the important feature of the middle layer, which emphasizes its agricultural possibilities in the coast climatic regime. The stratified parent material is sem-impervious to the downward movement of water, however, and drainage is required on the more gentle slopes.

The upper member of this group takes the form of a thick deposit of loamy sand, lying between the Maywood formation and the Vashon or upper Till, and is probably related to the Cordova sands (3) laid down near the close of the interglacial epoch. The C horizon of the profile developed on this material is remarkable for its firmness, being weakly cemented and semi-impervious to the downward movement of roots and water. The weakly cemented stratum is probably caused by a fluctuating water table due to high winter rainfall succeeded by summer dryness (7). This is the only deposit of loamy sand yet observed in British Columbia that is not loose and porous throughout its depth. The coarse texture of the profiles developed on the boulder clay (lower) and sandy (upper) members of the interglacial group stand against their utility for agriculture under coast climatic conditions.

*Boulder Clay Materials on the Interior Plateaux*

The main part of the interior of British Columbia is occupied by a system of plateaux bounded on the east and west by mountain ranges and divided by deep pre-glacial valleys of the main rivers and their chief tributaries. These old valleys received the runoff from the ice-sheet, and it was in them that damming and ponding occurred to form temporary lakes. Above the valley depressions the debris from the ice-sheet was dropped in place.

The plateau topography is mainly bold and steeply rolling, with elevations ranging from about 3500 feet in the south to about 2500 feet in the north. Unfortunately, soil surveys have not been made in this vast region and information is limited to observations while driving through parts of the plateau system crossed by the main roads. It would appear from such data that in some areas the erosive forces during deglaciation were not excessive, the boulder clay remaining comparatively fine textured. These areas have yielded soils ranging from sandy loam to clay loam, with varying amounts of stones and gravel; while in other parts of the country extensive washing away of the finer material has left sandy and gravelly districts of unknown extent.

*Glacial Lake Deposits of the Interior*

In the Okanagan Valley the most extensive glacial lake terrace systems occur where the largest existing tributary streams enter the main valley. The present elevation of Okanagan Lake is about 1120 feet, but the glacial lake terraces range up to about 2500 feet above sea level. The highest of these terraces are often gravelly and many of them have a hummocky surface, with a discontinuous layer of indurated boulder clay buried in the substratum. Both the hummocky surface and the cemented boulder

clay are accounted for by assuming that buried ice occupied an important part of the terrace volume during the process of deposition.

A covering of sandy loam or very fine sandy loam, sometimes without stones or gravel, and from 1 to 2 feet or more in thickness, generally overlies the coarse, stratified sands and gravels which form the bulk of the gravelly terraces. The fine-textured overlay was probably caused by tributary streams abandoning parts of their deltas, making them subject only to freshet overflow. The fine sediments were dropped by slow-moving water during the annual flood stage. This feature is commonly met with throughout the Province. In the Okanagan Valley its existence has been an inducement to use the land for irrigation, but with poor results where the fine-textured top layer is too thin.

Sandy terraces occur at almost the same or slightly lower elevations, and some of the higher sandy terraces also have a hummocky or rolling surface. The desirability of these terraces for fruit growing depends on the texture of the whole profile and the availability of irrigation water. The medium and very fine sands are certainly more desirable for development than the coarse loamy sand. In addition to hummocky topography many of the gravelly and sandy terraces are gently sloping towards the valley centre.

In the valley of the Thompson River and in the Okanagan Valley near Penticton, thick stratified deposits were formed in narrow lakes along the valley walls. Their general appearance indicates the former existence of valley glaciers, with ponding between the ice and mountain on each side of the valley. These narrow lakes were filled mainly with silts and fine sands, together with minor quantities of clay. On melting of the valley ice the deposits were left exposed as banks or terraces, with abrupt cliffs 100 feet or more in height, facing the valley bottoms. Tributary streams and freshet runoff have long since gullied these terraces, and the evidence suggests that their total destruction is only a matter of time, particularly where irrigation water has been applied to their upper surfaces.

Some of the most important areas of clay in the southern interior of the province occupy former glacial lake bottoms in the North Okanagan Valley and in the vicinity of Prince George. In both districts the clay has gently sloping valley bottom topography and the same stratification and remarkably heavy texture. Most of the clay was probably carried by the larger rivers discharging into glacial lakes, where it accumulated and settled, forming annual layers or varves. One cross-section near Prince George in the Central Interior, and another at Vernon in the Okanagan Valley, about 400 miles to the south, indicate a thickness of about 40 feet, with laminations $\frac{1}{4}$ inch thick or less, and varves about 2 inches thick, but interrupted here and there by thicker bands of silt and very fine sand.

*Soil Deposits Produced by the Post-glacial Erosion Cycle.*

On melting of valley ice, the glacial lakes drained away and the present lake depressions were left vacant. This process lowered the elevation of runoff water and caused the carving of new stream valleys through glacial lake terraces and valley bottom clays. In some cases the levels of lakes were raised to present elevations behind the outwash of streams entering at right angles to the main valleys.

In the Okanagan Valley freshet runoff from coulees of many temporary and permanent streams cut through the lake terraces and built up new fan cones whose lower fringes spread over previous clay deposits on the valley bottom. In narrow side valleys these fan cones sometimes occur with sufficient frequency to coalesce and completely hide former lake deposits. Where the lower fringes of fans cover glacial lake clay, the clay acts as an impervious substratum causing restricted drainage and the formation of intrazonal soils.

The completeness of textural grading in the post-glacial fan cones depends on their size and on the kind of debris being eroded during the freshet season. In the Okanagan Valley the larger streams have deposited a more or less complete range of textures which begin at the coulee mouth with an area of cobble. The cobble area is succeeded by gravelly sandy loam, sandy loam, loam, clay loam and clay. The finer textures are streaked with lenses of gravel and sand owing to the changing course of freshet runoff.

On a larger scale the main rivers have carried out the same sorting process. The Fraser River and its main tributaries cut new channels through glacial lake deposits and transported vast quantities of fine sands, silts and clays, which were discharged into the post-glacial delta between Chilliwack and the Coast. To a smaller extent than formerly this process still continues. The modern delta is being built out into the Strait of Georgia at the rate of about 10 feet a year, mainly during the freshet stage (5). In addition to the delta deposits, a substantial part of the river load was dropped along its course, leaving second bottoms and more recent floodplains of some agricultural importance. Textural grading in the post-glacial delta of the Fraser ranges from loam to clay, and soil types which developed on this material have been named Langley, Haney, Milner, Monroe and Ladner series (6).

## AGRICULTURAL SIGNIFICANCE OF PARENT MATERIALS

Soils derived from interglacial deposits have received only a limited study. In the district between Courtenay and Menzie's Bay on Vancouver Island, soils formed on fine textured marine sediments are used to some extent for mixed farming.

The boulder clay soils, which overlie the interior plateaux above the valley depressions, would appear to have textures suitable for farming in many parts of the region. Present uses, however, are restricted to forestry and grazing, with the exception of a few small localities in the black earth belt where topography is sufficiently modified for grain growing.

Soils developed on former glacial lake deposits are of present importance for settlement. In the humid climates the heavier textured classes, from loam to clay, have received most attention. In the semi-arid districts gravelly and sandy terraces have been irrigated. These soils are farmed in the Okanagan Valley, the Kootenay district, in the Cariboo and in the Central Interior.

Fine textured soils formed on materials transported and deposited during the post-glacial erosion cycle are the most sought after and most extensively developed in British Columbia. The Recent soils, having

undeveloped or feebly developed profiles, are most readily adaptable for crop production. Chemical information on soil profiles from different parts of the Province is very limited, but the small amount of data now available indicates a high calcium content in both humid and semi-arid climates. In humid climates, however, the calcium is in slowly available form, and addition of lime to the soil is necessary for certain crops.

The texture of the whole soil profile is of significance as a land use factor when applied mainly to soils developed on coarse textured valley filling deposits, with separate treatment for humid and semi-arid climatic regimes. That is to say, the humid coastal climate of British Columbia is one in which high winter precipitation is succeeded by summer dryness. Under these conditions the drought resistance afforded by fine textured profiles is a necessary requirement for mixed farming. Observations in the Lower Fraser Valley and on the east shore of Vancouver Island indicate that successful settlement has not developed on gravelly sandy loams and loamy sands with porous substrata. Selection of the texture profile holding the marginal position would enable a land utilization boundary to be drawn between the forest and the farm in the humid climatic zones.

In the semi-arid interior valleys, where irrigation is used, the deep sandy loam profiles are highly prized. The loamy sands have supported orchards since 1905, but appear to be subject to washing on the steep slopes. In rolling topography, areas of loamy sand tend to lose the entire solum, but whether this will lead to disuse is speculative.

The gravelly terraces, which often have a covering of 18 inches to 2 feet of sandy loam resting on stratified gravel, are in a much more doubtful category. Large amounts of irrigation water are used on these profiles during the summer season, which results in leaching and a tendency for the soil covering to wear thin. In rolling areas there is reason to doubt that the soil will survive more than one generation of fruit-growers. Local experience suggests that gravelly terraces with a thin soil covering will not support a permanent agriculture and should not be included in new irrigation projects.

## SUMMARY

During the Pleistocene, British Columbia was over-ridden by glaciers, the bulk of the materials forming existing B.C. soils being derived from the debris of the ice-sheet. Since only a shallow solum has been produced by post-glacial weathering, the underlying parent material must be considered in land use classification.

Organization of parent materials occurred as a result of: (1) glacier movement, with freshly ground materials being mixed with Tertiary soil residue; (2) ice recession and advance; (3) ice decay, followed by water transportation and textural grading during runoff; and (4) subsequent erosion.

A number of products were formed through combination of these processes, among them being interglacial deposits on Vancouver Island, boulder clays on the interior plateaux, glacial lake deposits, and soil materials laid down during the post-glacial erosion cycle.

Agricultural significance of parent materials depends upon the texture of the whole soil profile. In humid coastal and interior regions fine-

textured profiles prove of most value; coarse-textured soils being more important in the irrigated semi-arid districts of the interior. The most fertile and highly valued soils have developed on fine-textured materials transported and laid down during the post-glacial erosion cycle. In coastal and interior regions certain coarse-textured profiles are submarginal for cultivation.

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## Other Soils Group Papers

The following paper, read to the Soils Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939, has been published in a previous issue of Scientific Agriculture.

Rivaz, C. P., and G. C. McLaren, Standardization of Rapid Soil Testing Technique. Scientific Agriculture 20 : 120-130. 1939.

The following papers, although read to the Soils Group, are being held by the authors until additional data are received for incorporation.

Spilsbury, R. H. and E. W. Tisdale—Native Vegetation Types in Relation to Vertical Soil Zonation.

Salisbury, H. F. and W. A. DeLong—A Study of the Organic Fraction of some Quebec Soils.

DeLong, W. A.—Seasonal changes in Easily Soluble Manganese and Phosphorus in Appalachian Podzol.

The paper entitled "Soil Management Studies in Relation to the Tobacco Crop in Ontario" by R. J. Haslam, while listed on the program, was not read to the Soils Group, being held in abeyance until certain features of the work are completed.

# THE RESPONSE OF THE LIVINGSTON ATMOMETER TO SINGLE METEOROLOGICAL FACTORS[1]

W. J. Staple[2] and J. J. Lehane[3]

*Soil Research Laboratory, Dominion Experimental Station, Swift Current, Sask.*

The Livingston atmometer has been widely used in America to measure the evaporating power of the atmosphere. In evaporation experiments at Swift Current, it became necessary to determine more definitely what this evaporating power meant in terms of single meteorological factors. Since the analytical study of the instrument was commenced, a similar work by Borne (1) in Germany has been brought to our attention. The general conclusions resulting from our controlled experiments are the same as those reported by Borne. Additional data are presented to show how the ordinary field observations check with the calibration curve.

## WIND TUNNEL EXPERIMENTS

The test experiments were conducted in a wind tunnel which gave a uniform flow of air at velocities up to 30 miles per hour. Temperature and humidity could not be varied readily but were read at short time intervals using wet and dry bulb thermometers. Wind velocity records were obtained by means of a pitot tube connected to a sloping alcohol manometer. The white sphere type of atmometer was used in all the tests. Evaporation loss was calculated from the rate of movement of a thread of mercury along a calibrated capillary tube. Using this apparatus, evaporation readings could be taken in one minute or less, thus eliminating error due to change in temperature and humidity. The experiments were conducted during winter in a well lighted basement room; no data were obtained on radiation or insolation effects.

After each change in wind velocity it was necessary to allow some time for lag in the evaporation rate before taking the next reading. As might be expected, the lag decreased with increase in wind velocity. Data presented in Figure 1 were recorded only after the evaporation rate had reached a definite equilibrium point.

The smooth curve in Figure 1 was obtained by plotting the atmometer loss per unit wet thermometer depression against the wind velocity. The uniformity of the experimental points testifies to the accuracy of the assumption that the atmometer loss varies directly with the wet bulb depression.

The relationship was tested further by holding the wind velocity constant and varying the humidity. This method was subject to some inaccuracy since it was difficult to hold the humidity at a definite value until the atmometer reached equilibrium. However, a reasonably smooth straight line relationship was obtained when the evaporation loss was plotted against temperature depression. This result is in agreement with

[1] Contribution from the Experimental Farms Service, (P.F.R.A.), Dominion Department of Agriculture, Ottawa. Read to the Soils Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.

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that obtained by Turnage and Shreve (2). Borne's results (1) were expressed as evaporation per unit difference in vapour concentration instead of per unit difference in wet and dry bulb temperature. For most practical situations, these two differences may be considered proportional.

The wind tunnel trials indicate that the white sphere atmometer reflects meteorological conditions accurately when an equilibrium condition is maintained. Satisfactory readings result when the average wind velocity is high or when changes in velocity or humidity take place slowly. Differences in radiation influence were not significant under the conditions of our experiments.

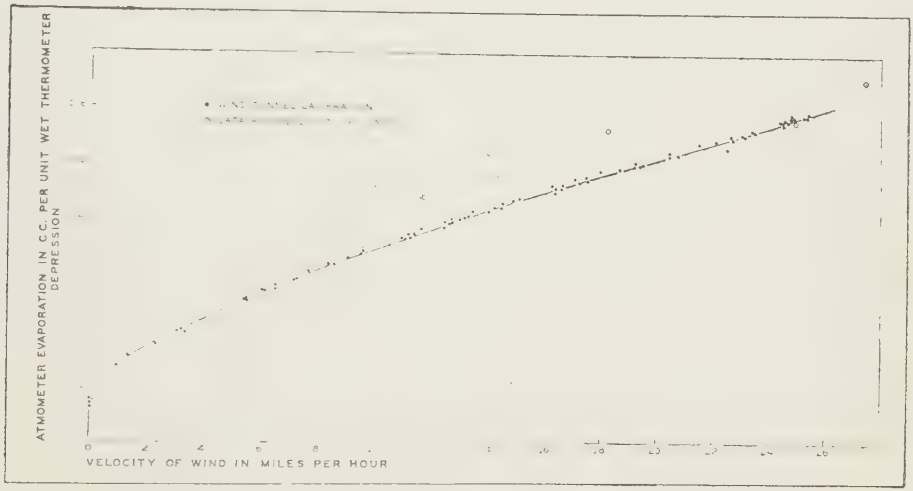


FIGURE 1

## ATMOMETER RESPONSE IN THE FIELD

The scattered points above the curve in Figure 1 were obtained out-of-doors during June and July, 1937. The atmometer loss was checked with wind velocity and humidity records taken at 5 feet above the ground. Each point represents the hourly evaporation averaged for the period 7.00 a.m. to 5.00 p.m. daily. As humidity and wind velocity change markedly throughout the day, data obtained in this way are not strictly comparable to those obtained in the wind tunnel. The purpose was to find what happens under field conditions when atmometers are weighed twice daily.

The points show that the evaporation per unit temperature depression was greater and more varied than the tunnel results predicted. The greater loss in the open would appear to be due partly to insolation. Atmometers sheltered from direct sunlight but exposed to the wind, show a measurable decrease in evaporation compared to instruments fully exposed. The scattering of points can be explained largely in the averaging of widely different temperature depressions and wind velocities. Lag in the atmometer may play a part, depending on the magnitude and rate of change of wind velocity and humidity.

A calibration curve, such as that shown in Figure 1, is useful in the interpretation of atmometer data in the detailed type of field or laboratory experiment. For example, in ecological studies, records of air temperature, wind velocity and atmometer loss are often obtained near various types of vegetation. Figure 1 gives the atmometer loss per unit wet bulb depression for any given wind velocity. Then, knowing the rate of atmometer loss and the air temperature, the average wet bulb depression and water vapour concentration can be calculated. The same method may be used to calculate integrated values of the vapour concentration at different heights above the ground.

In the above examples, the radiation influence is disregarded. For average out-of-doors conditions, a calibration curve somewhat similar to Figure 1 but with slightly higher evaporation values, might be useful. In many cases, however, atmometer results in different habitats are only comparative and the radiation factor may be neglected.

## ACKNOWLEDGMENTS

The authors are indebted to Dr. J. L. Doughty for assistance and co-operation throughout the course of this work.

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## BOOK REVIEW

HUMUS: ORIGIN, CHEMICAL COMPOSITION, AND IMPORTANCE IN NATURE. By Selman A. Waksman, Rutgers University. (Second revised edition; 526 pages, 44 illustrations. 1938. Williams and Wilkins Company, Baltimore.)

The fact that a second edition of "Humus" was required within three years of the appearance of the first edition speaks for the popularity and demand for this book. The second edition (1938) has been revised and additional references added.

The author has arranged the material in three main sections requiring 415 pages.

*Part A*—Four chapters devoted to "Historical Development of Our Knowledge of the Chemical Nature of Humus, Its Formation, and Its Role in Plant Nutrition."

*Part B*—Nine chapters on the "Origin and Nature of Humus."

*Part C*—Five chapters discussing the "Decomposition of Humus, Its Functions and Applications."

The appendix, devoted to the methods of analysis of humus, is a very important addition to the preceding pages. This is followed by a very comprehensive bibliography of upwards of 1600 references.

"Humus" is the most complete and up-to-date book of its kind published in any language. The author is eminently qualified, as the result of long years of research and teaching, to supply us with a text that is well suited to the requirements of teachers, investigators and students.

F. A. WYATT.

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ng and 3 feet apart.
The plots each year were replicated 4 times in a Latin Square. Within the rows plants were spaced at 12, 18, 24 and 30 inches. The following gives the number of plants grown on each plot, also the number that would be required on an acre basis:

12 inches apart gave 14 plants per plot = 14520 per acre.
18 inches apart gave 10 plants per plot = 9680 per acre.
24 inches apart gave 8 plants per plot = 7260 per acre.
30 inches apart gave 6 plants per plot = 5800 per acre.

Plants spaced at 12 inches and staked require 14,520 stakes per acre. In order to obviate the use of such large numbers of stakes a system of wiring was used. Four plot rows, end to end, were approximately 66 feet long. A post 4 inches square was firmly imbedded at the end of each row, and at a height of 54 inches from the ground a number 14 gauge wire was tightly stretched between posts. A second wire was put 6 inches above the ground level. At each plant a string was tied to the top and bottom wire and as plants grew they were twisted around the string. To afford additional support a stake 2 inches square was driven in at 15 foot distances along the row to which the top wire was fastened. The bottom wire can be avoided by tying the string to a small peg driven in beside each plant. This method of training closely set plants requires considerably

[1] Contribution No. 546 from the Division of Horticulture, Experimental Farms Service, Dominion Department of Agriculture, Ottawa. Read to the Horticultural Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.
[2] Assistant.

less material and less labour than does the method of staking. The greatest saving of time is in tying, and pruning is also made easier. The plants each year were trained to a single stem.

## RESULTS

Tables of plot yields are not given, as summaries in this experiment record comparative yields satisfactorily, the results each year between plots having been very uniform. The following tables show the various data obtained.

TABLE 1.—AVERAGE YEARLY YIELD OF TREATMENTS FROM FOUR PLOTS

| Year | 12-inch | 18-inch | 24-inch | 30-inch |
|---|---|---|---|---|
| | lb. | lb. | lb. | lb. |
| 1935 | 57.1 | 35.6 | 32.2 | 24.9 |
| 1936 | 78.7 | 63.3 | 61.5 | 46.2 |
| 1937 | 69.1 | 60.4 | 45.6 | 36.8 |
| 1938 | 58.7 | 45.1 | 42.8 | 30.9 |

In Table 1 a consistently higher yield is shown for close planting, and the 12-inch distance is recommended. This trend prevailed throughout the experiment in the various plots from year to year.

TABLE 2.—AVERAGE YEARLY YIELD PER PLANT FROM FOUR PLOTS OF EACH TREATMENT—

| Year | 12-inch | 18-inch | 24-inch | 30-inch |
|---|---|---|---|---|
| | lb. | lb. | lb. | lb. |
| 1935 | 4.1 | 3.5 | 4.0 | 4.2 |
| 1936 | 5.6 | 6.3 | 7.7 | 7.7 |
| 1937 | 5.0 | 5.9 | 5.7 | 6.1 |
| 1938 | 4.2 | 4.6 | 5.3 | 5.5 |

In Table 2 the average figures do not, nor do those of the individual plots, show as marked a trend as the total yield figures per plot and it is therefore assumed that close planting decreases to only a very limited extent the yield of individual plants.

TABLE 3.—AVERAGE NUMBER OF FRUITS PER PLANT FROM FOUR PLOTS OF EACH TREATMENT

| Year | 12-inch | 18-inch | 24-inch | 30-inch |
|---|---|---|---|---|
| 1937 | 14.2 | 17.0 | 16.1 | 18.7 |
| 1938 | 14.8 | 15.0 | 18.9 | 15.5 |

The average figures in Table 3 do not, nor do those of the individual plot yields, show any trend in number of fruits per plant and it is therefore assumed that distance of planting has no effect on this aspect of production.

The figures in Tables 4 and 5 do not, nor do those of the individual plot yields, show any consistent trend as to the percentage of culls or the size of fruit for the different treatments. There is, however, a slight upward trend for size of fruit for more distant spacing. It is therefore assumed that distance of planting has no appreciable effect on these aspects of production.

TABLE 4.—AVERAGE PERCENTAGE OF CULLS FROM FOUR PLOTS OF EACH TREATMENT

| Year | 12-inch | 18-inch | 24-inch | 30-inch |
|---|---|---|---|---|
| | % | % | % | % |
| 1937 | 21.3 | 20.8 | 23.9 | 16.9 |
| 1938 | 26.1 | 33.6 | 30.5 | 33.6 |

TABLE 5.—AVERAGE SIZE OF FRUIT FROM FOUR PLOTS OF EACH TREATMENT

| Year | 12-inch | 18-inch | 24-inch | 30-inch |
|---|---|---|---|---|
| | oz. | oz. | oz. | oz. |
| 1937 | 5.6 | 5.7 | 5.7 | 5.6 |
| 1938 | 4.5 | 4.8 | 4.7 | 5.1 |

## DISCUSSION AND CONCLUSIONS

Tomatoes for many years in many producing centres in North America have been pruned and tied to stakes. In recent years this method of production has been on the increase. The practice of pruning and staking tomatoes, however, is not universally popular. Huelsen (2) in Illinois states that it is always dangerous to remove any part of the foliage. Allen and Talbot (3) in Missouri found staked plants to yield more than unstaked plants and suggest 2 to 3 feet apart in rows 3 to 4 feet apart. In Ontario, MacLennan and Presant (4) suggest plants 18 inches apart in rows spaced $3\frac{1}{2}$ to 4 feet. Another method practised amongst large growers in Ontario is to plant 2 adjacent rows 2 feet apart with plants 18 inches apart and leave 4-foot spaces between double rows. This is not as close planting as 12 inches apart in rows spaced 3 feet apart. Beattie (5) refers to planting distances in Texas, Mississippi, Florida and New Jersey and in the New England States, where tomatoes are grown under the most intensive pruning and staking methods. The number of plants used in these various states varies from 3000 under Florida conditions to 10,000 under New England States conditions where a double row system is used, pairs of rows being 18 inches apart and plants 18 inches in the row leaving 42 inches between double rows. The approximate distance on this basis is only slightly greater than with plants 12 inches apart in rows 3 feet apart, with the number of plants per acre 14520. The figure of 10,000 plants given by Beattie would indicate that the exact distances under field conditions are not closely followed.

The data submitted in Table 1 show the yield per acre for 12, 18, 24 and 30 inches to be 63,646, 49,368, 44,044 and 33,389 pounds. Under the

conditions of this experiment, failure to plant close to the maximum number of plants would under field conditions represent an appreciable loss of tonnage per acre. Table 2 brings out the fact that close planting decreases the yield from individual plants to a small extent but not enough to offset the advantage of the total plant yield. Tables 3, 4 and 5 do not show a sufficiently marked trend to account for the smaller yield per plant from close planting. In Table 5 the trend would however, indicate a slight increase in size of fruit. It is assumed here that several factors are involved in the decreased yield per plant, each exerting a small influence which did not clearly manifest itself under the conditions of this experiment.

Under a wide variety of soil, moisture and climatic conditions it is to be expected that different or modified results would be obtained. Conditions in 1938 provided an opportunity to make some measurements in respect to variable soil fertility and a decreased supply of moisture. In this year of the experiment one-half of the plots were on considerably more fertile soil than the other, yet the ratio of increase from close to distant planting was the same as with plots on fertile soil. The year 1938 was one of very low rainfall, especially during the season from June to September inclusive. For the years 1935 to 1938 the total rainfall, June to September, was respectively 12.54, 11.16, 10.23 and 3.84 inches. The low precipitation during 1938 gave the same differences in ratio of yield between different distances as were obtained in the 3 previous years. Close planting under the soil conditions of this experiment does not make moisture a limiting factor.

The picking season each year was divided into weekly intervals, and throughout the 4 years of the experiment the largest amount of early ripe fruit was from the 12-inch spacing, the yield of early ripe fruit bearing a definite relationship to the total yields at the end of the season.

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# A SCORING SYSTEM FOR CANNING TOMATOES[1]

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The grower of canning tomatoes desires a variety that will give maximum yields with a high percentage of No. 1 fruit. The fruits must ripen evenly and be as free as possible from sunscald or green top. They must be free from roughness, ridges, lobing, cracking and splitting. They should preferably be round or oval with a diameter not less than $2\frac{1}{2}$ inches nor more than $2\frac{7}{8}$ inches.

After canning, the product should be bright red in colour and should contain as many whole tomatoes or large pieces as possible. It should have a high percentage of drained solids and should also have a high percentage of soluble solids as shown by a refractometer reading. The fruit should have a good flavour and it should be free from large cores.

To determine the most suitable variety when many strains and varieties are being tested, a scoring system has been devised to show concisely the extent to which each variety meets all the requirements of both the grower and the canner. Fifty per cent of the score is allowed for cultural qualities, that is, requirements of the grower; and fifty per cent is allowed for canning qualities, that is, the requirements of the canner. This scoring system is adapted for experimental hand packing. Deductions for defects might have to be modified for different canning procedure.

## CULTURAL SCORE

Yield, percentage of culls, size of tomato, shape, and size of cavity have been allotted points after careful consideration of the relative importance of each in judging the merits of the fruit as it arrives at the cannery

### *Yield*

In harvesting, all ripe fruit is picked and graded as marketable and unmarketable. The picker carries 2 pails and the product is weighed and totalled at the end of each row at each picking. At the end of the season, the yield of each variety is totalled. Special efforts are made to maintain a full stand of plants in each plot. However, to compensate for the occasional blank due to disease or other mishap, yields are reduced to the basis of a single plant by dividing the total yield by the number of plants harvested. Yields are then arranged in descending order and divided equally into 4 parts. The top quarter is allotted 14 points, the next 10.5, the next 7.0 and the lowest 3.5 points.

### *Percentage of Culls*

The percentage of culls is calculated from the total yield of fruit and the total yield of culls per plant for the season. The resulting figures are arranged in ascending order and divided into 4 equal groups. The lowest quarter is allotted 14 points, the next 10.5, the third 7.0 and the fourth 3.5. If any variety shows an exceptionally high percentage of culls, the score may be cut to zero.

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*Size*

Fruit calipers graduated in 32nds of an inch are used to measure the polar diameter and the maximum and minimum equatorial diameters of 10 fruits selected at random from each variety. Fruits averaging $2\frac{3}{4}$ to $2\frac{7}{8}$ inches are allotted 10.0 points. Fruits averaging $2\frac{1}{2}$ to $2\frac{3}{4}$ inches and fruits averaging over $2\frac{7}{8}$ inches are each allotted 7.0 points, while very small fruits averaging less than $2\frac{1}{2}$ inches are cut to 3.5 points.

*Shape*

The relation of polar diameter to equatorial diameter is considered when scoring for shape. Fruits that are round or oval and smooth are allotted 6 points. If decidedly oval and ridged or lobed they are allotted 4.0 points; and if cracks and splits occur they are cut to 2 points. If cracking is very bad or fruits are very rough, the score is cut to zero.

*Cavity*

If the fruit is smooth with a shallow, narrow cavity showing little loss on peeling, the score is 6 points. A medium wide or deep cavity scores 4 points; and if the cavity is very deep or wide, the score is 2 points.

## CANNING SCORE

At least three cans of each variety are canned at harvest time. Later in the season the cans are opened individually and scored for colour, drained weight, total solids by refractometer, and number of whole fruits. During the process of canning, the fruits are scored for flavour, cells, cell walls, and core.

When the cans are being scored the can is first weighed in grams. By counterbalancing an empty can the net weight of can contents is obtained. The contents are then dumped on to a screen, two meshes to the inch, and allowed to drain for one-half minute. From the screen the drained fruit is transferred to granite pans for examination while the juice is measured in graduated cylinders. From its volume the percentage of dry matter is determined. Refractometer readings are made of the juice of each sample immediately after draining.

*Colour*

Bright red fruits are scored 3, light red 2, the presence of yellow ribs cuts the score to 1, and if a green shoulder occurs that particular fruit is cut to $\frac{1}{2}$ point. The score for the can is calculated on the basis of 4 fruits. The number in each class is multiplied by its score, then these are totalled and reduced to a basis of 4 fruits. For example, if 3 bright red, 1 light red, 1 yellow rib, and 1 green shoulder occur in a can, the score would be 3 times 3 for bright red, plus 1 times 2 for light red, plus 1 times 1 for yellow rib, plus 1 times $\frac{1}{2}$ for green shoulder; making a total of $12\frac{1}{2}$ points. There are 6 fruits in the can so the score of 12.5 must be multiplied by 4/6, giving a score of 8.33 points for colour.

*Drained Weight*

After deducting the weight of juice in grams (which for working purposes is equal to the volume in cubic centimetres) from the total weight of the contents of the can, the percentage of remaining solids is calculated and arranged in descending order. The top one-third scores 10 points,

the middle third scores 7, and the lower third scores 3.5 points. If the number is very large, the list may be divided into 4 groups, scoring 10, 8, 6 and 4 points respectively.

*Number of Whole Fruits*

A No. 2½ can is filled with four tomatoes of average size. In addition, one tomato is broken up to provide liquid to fill the interstices. If the tomatoes are very large, no whole tomatoes may be included but a number of large pieces which give the can a fairly attractive appearance when opened. As the pieces decrease in size, the can loses its attractiveness. A detailed score has been compiled to cover all possible combinations, as follows:

| | |
|---|---|
| 3 or more whole fruits | 10 points |
| 2 whole fruits, rest large pieces | 8 |
| 2 whole fruits, rest small pieces | 6 |
| 1 whole fruit, rest large pieces | 7 |
| 1 whole fruit, rest small pieces | 5 |
| 1 whole fruit, rest of can mush | 4 |
| 0 whole fruits, all large pieces | 7 |
| 0 whole, but 4 large pieces | 7 |
| 0 whole, but 3 large pieces | 6 |
| 0 whole, but 2 large pieces | 5 |
| 0 whole, but 1 large piece | 4 |
| Whole can mush | 0 |

*Total Solids by Refractometer*

A total of 7.5 points has been allotted in the score for total soluble solids. In scoring, the actual refractometer reading is taken.

*Core*

It has been found easier to determine the presence of cores in the fresh fruit than in the canned product. The varieties are scored by cutting 5 fruits. If little or no core is found, the score is 2.5 points; a medium sized core in one or more fruits scores 1.5; and a large core in one or more fruits scores 0.5 points.

*Cells and Cell Walls*

These are determined when the fruits are cut for core. Small cells or locules score 1.5, medium cells score 1.0, and large cells score 0.5 points. Thick locule or cell walls score 2.5 points, medium walls score 1.5, and thin cell walls 0.5 points.

*Flavour*

Flavour is largely a matter of personal choice. However it has been allotted 5 points in this scoring system. Full points are allowed unless the flavour is insipid or extremely acid, when the score would be cut 2 to 4 points. Unusual flavours such as are found in some Italian varieties, if considered undesirable, are cut one or more points.

*Earliness of Maturity*

In the Okanagan Valley it is a common practice for tomato growers to ship semi-ripe fruits from their crop until the plants come into full bearing.

About this time the price for semi-ripe tomatoes drops off rapidly as the market becomes more or less glutted. The canneries begin to operate when this condition occurs. Nearly all varieties are bearing ripe fruits by this time and earliness of maturity is not an important factor from the standpoint of canning tomatoes. Occasionally a very late variety is found which is only coming into full bearing when the cannery season closes or when frosts are likely to occur. The experimental picking closes at a time to coincide with the cannery season, usually the end of September. The reduced yields from these late varieties automatically place them well down in the list. Accordingly, no special provision is made for evaluating season of maturity in this scoring system. However, if it is considered desirable to put a premium on earliness of maturity, an arbitrary date such as Labour Day may be selected. Because of the long week-end, an effort is usually made to complete picking of all plots on the Saturday prior to Labour Day and this makes a suitable date at which the yields may be divided. All yields prior to Labour Day can be totalled and arranged in descending order. They may then be divided into 4 equal groups and scored on the basis of total yield up to that date.

Occasionally a variety may be included in the tests that has an exceptionally high percentage of culls; that is very subject to disease; that is too small for economical handling; or in some other way is undesirable for commercial purposes. In such cases, the variety would be scored in the ordinary way and a warning remark added by a foot-note indicating the undesirable characteristic.

## SUMMARY

A scoring system has been devised for comparison of cultural and canning qualities of tomatoes.

The relative importance of different characteristics has been considered in allotment of points.

Detailed methods for scoring have been worked out.

Scores allotted for different characteristics are as follows:

| | | |
|---|---|---|
| *Cultural Characteristics* | | |
| Yield | 14.0 | |
| Percentage of culls | 14.0 | |
| Size of fruits | 10.0 | |
| Shape (including cracks) | 6.0 | |
| Cavity | 6.0 | |
| Total | | 50 |
| *Canning Characteristics* | | |
| Colour | 12.0 | |
| Drained weight | 10.0 | |
| Number of whole fruits | 10.0 | |
| Total solids by refractometer | 7.5 | |
| Core | 2.5 | |
| Cell size | 1.5 | |
| Cell walls | 1.5 | |
| Flavour | 5.0 | |
| Total | | 50 |

# CHEMICAL CONSTITUENTS OF SOME FRUITS GROWN IN BRITISH COLUMBIA[1]

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## INTRODUCTION

Information concerning the chemical constituents of fruits is useful in determination of such factors as maturity, suitability for processing, and purity of manufactured products. For instance, the maturity of cherries is closely correlated with sugar content; the suitability of prunes for dehydration depends largely on the percentages of sugar and acid they contain; and the insoluble solid content of berries is of value in ascertaining the purity of products made therefrom.

With these facts in mind, analysis of fruits grown commercially in British Columbia was begun in 1931. Additional data have been secured each year and the work is still in progress.

## MATERIALS AND METHODS

Analyses have been made of the following varieties:

*Apples:* Delicious, Grimes Golden, Jonathan, McIntosh, Newtown, Ontario, Rome Beauty, Northern Spy, Stayman, Wagener, and Winesap.

*Apricots:* Blenheim, Royal.

*Peaches:* Valiant, Vedette, Veteran, No. 4108, J. H. Hale, and Elberta.

*Cherries:* Royal Ann, Bing, Lambert, Deacon.

*Prunes:* Italian.

*Grapes:* Angevine, Agawam, Burgunder, Blau Frankisch, Campbell Early, Chasselas Rouge, Concord, Delaware, Fredonia, Muscat Ferdinand de Lessups, Muscat Ottonel, Moore's Early, Niagara, Ontario, Oberlin 595, Patricia, Pearl of Csaba, Portland, Rauschling, Riesling-Sylvaner, Seibel 2838, Seibel 5279, Seibel 5455, Seneca, Sheridan, Worden.

*Currants:* Boskoop Giant, Climax, White Grape, Perfection.

*Strawberries:* Royal Sovereign, British Sovereign, Beauty, Fairfax, Laxton, Red Heart.

*Raspberries:* Cuthbert, Latham, Lloyd George, Newburg, Taylor, Viking.

Most of the fruit analyzed was grown on the Summerland Experimental Station. However, samples of Delicious apple were secured from Salmon Arm, Vernon, Winfield, and Oyama. Samples of British Sovereign strawberry were secured from Victoria, Kelowna and Nelson; Royal Sovereign from Kelowna; Beauty and Fairfax from Nelson; Laxton and Red Heart from Victoria. Cuthbert, Lloyd George, and Viking raspberry were secured from Kelowna as well as from the Experimental Station plantation.

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In many cases analyses were made of fruit of the same variety grown in different seasons. For instance, with the Delicious apple, fruit was secured from two trees in each of the Salmon Arm, Vernon, Oyama, and Winfield districts in 1931, and from the same trees in 1932. Furthermore, the fruit from each of these trees was graded for red colour into Extra Fancy, Fancy and Cee, each grade being analyzed separately.

With all fruits, material for analysis was taken from sufficiently large lots to ensure representative samples. For example, in comparing varieties of apples, samples were taken from 40-gallon barrels of juice pressed from "orchard run" fruit.

With apples and grapes, the fresh expressed juice was used in the analyses. With the other fruits, analyses were made on the pulped fruit. With few exceptions, analyses were made when the fruit was at the eating-ripe stage of maturity.

Data were secured concerning the following constituents: solids: total, water insoluble, and soluble; sugars: total, reducing, and sucrose as invert; acid; tannin; pectin; ash; and pH.

These constituents were determined according to the methods of the Association of Official Agricultural Chemists. The Lane and Eynon method was used in the estimation of sugars. Soluble solids were estimated by use of a Zeiss refractometer graduated to read in percentage sugar by weight at 20° C.

## RESULTS

The results of the analyses are expressed in percentage by weight of the fresh fruit or juice analyzed, the data secured being embodied in the tables which form an appendix to this paper. The results may be briefly summarized as follows:

### *Apples*

In juice from apples the percentage of total sugar ranged from 10.7 to 14.7, acid from 0.25 to 0.57, and tannin from 0.02 to 0.05.

Delicious, Grimes Golden and McIntosh were lower in acid and tannin than Jonathan, Ontario, Stayman and Winesap.

Delicious, Jonathan, Stayman and Winesap had comparatively high average sugar content, but there were marked differences in the sugar content of the same variety in different seasons. For instance, in comparable samples of Delicious picked from the same trees in two different years, there were differences in sugar content of over 3%. Similarly, there were differences of over 3% in total sugar content of Delicious apples secured from different districts in the same season. Furthermore, in Delicious apples picked from the same tree on the same day, there was about 1% more sugar in Extra Fancy than in Cee grade fruit.

### *Apricots*

In Blenheim and Royal apricots analyzed at shipping maturity, total sugar averaged about 9%, and acid 1.6%, whereas in eating-ripe fruit sugar averaged over 11 and acid about 1%.

*Peaches*

In peaches, sugar content ranged between 7 and 11%, and acid between 0.5 and 0.8%.

*Cherries*

Royal Ann, Bing, Lambert and Deacon cherries of satisfactory maturity for glaceing had a soluble solid content of about 14.5, 14.5, 15 and 12% respectively.

Royal Ann, Bing, Lambert and Deacon cherries of too advanced maturity for glaceing had soluble solid contents as high as 20, 24, 20 and 18% respectively.

Fruits of Royal Ann with a fairly high soluble solid content produced a glaced product of satisfactory colour but were inclined to split in the brine solution.

Fruits of the dark varieties gave a glaced product of undesirable dark colour when picking was delayed until they had passed the "tomato red" colour.

*Prunes*

The percentage of Italian prunes developing insufficient sugar to make a good dehydrated product varied from 26 to 57% of the total crop in different seasons.

Flotation in brines of different strength proved an effective means of separating large quantities of prunes of different sugar content.

Prunes left on the tree to ripen showed a progressive decrease in acid for several weeks after they had attained maximum sugar content.

*Grapes*

Total sugar content of the 26 varieties of grapes tested ranged from 12 to 25%, acid from 0.38 to 2.25%, and tannin from 0.006 to 0.208%.

Grapes of the following varieties were found to produce medium sweet wines of good quality: Burgunder, Campbell Early, Muscat Ferdinand de Lessups, Muscat Ottonel, Portland, Rauschling, Riesling-Sylvaner, Seibel 2838, and Seibel 5279.

*Currants*

With black, white, and red currants, total sugar content ranged between 5.3 and 6%; acid content between 1.5 and 2%; and pectin between 0.6 and 1.7%; red currants being highest in acid and black currants notably high in pectin.

*Strawberries*

In five varieties of strawberries the percentage of insoluble solids ranged between 2 and 4%, total sugar between 5.5 and 8.5%, acid between 0.66 and 1.47%, and pectin between 0.45 and 0.85%.

The insoluble solid content of British Sovereign strawberries secured from three districts the same season was 2.3, 3 and 4% respectively.

*Raspberries*

In six varieties of raspberries analyzed, the percentage of insoluble solids ranged between 4.5 and 6.4%; soluble solids between 9.4 and 14.2%; acid between 1.2 and 2.1%; and pectin between 0.53 and 0.70%.

The total solid content of Lloyd George raspberries picked from the same patch was 16% one year and 13% another.

## DISCUSSION

The variation in composition of fruits of different varieties, and in the composition of the same variety from different districts and in different seasons, which is revealed in Appendix Tables 1 to 11, is of importance to the processing industry. For instance in canning, preserving and juice manufacture, variations in sugar content of the fresh product should be adjusted by varying the amount of sucrose or other sugar added. In the making of wine, variations in the sugar, acid and tannin content of the grapes should be taken into account in blending. Similary in the making of fruit juices, cider and vinegar, the process should be modified in accordance with the analysis of the fresh juice.

With cherries, soluble solid content can be used as a means of determining the suitability of the fruit for glaceing, and with prunes, grading in accordance with sugar content is essential in order to secure a product of uniform quality.

## APPENDIX

Table 1.—Analyses of apple juice from different varieties

| Variety | Year | Specific gravity | Acid as malic | Sugar as invert | | | Tannin |
|---|---|---|---|---|---|---|---|
| | | | | Total | Reducing | Sucrose | |
| | | | % | % | % | % | % |
| Delicious | 1933 | 1.052 | 0.28 | 12.45 | | | 0.023 |
| | 1936 | | .23 | 14.03 | 10.04 | 3.99 | .023 |
| Grimes Golden | 1933 | 1.046 | .29 | 10.75 | | | .025 |
| Jonathan | 1933 | 1.060 | .53 | 13.75 | | | .030 |
| | 1936 | | .57 | 12.75 | 10.05 | 2.70 | .030 |
| McIntosh | 1933 | 1.047 | .30 | 10.79 | | | .021 |
| | 1936 | | .37 | 12.97 | 11.69 | 1.28 | .021 |
| Newtown | 1933 | 1.053 | .45 | 12.08 | | | .031 |
| | 1936 | | .53 | 12.45 | 10.14 | 2.31 | .023 |
| Ontario | 1933 | 1.050 | .56 | 11.15 | | | .027 |
| Rome Beauty | 1933 | 1.054 | .39 | 12.48 | | | .034 |
| Spy | 1933 | 1.052 | .43 | 11.94 | | | .035 |
| Staymen | 1933 | 1.064 | .42 | 14.74 | | | .052 |
| Wagener | 1933 | 1.052 | .37 | 12.19 | | | .027 |
| Winesap | 1933 | 1.058 | .48 | 13.23 | | | .042 |

TABLE 2.—ANALYSES OF DELICIOUS APPLE JUICE FROM DIFFERENT DISTRICTS AND DIFFERENT SEASONS

| District and strain | Year | Dry* matter | Acid as malic | Sugar as invert | | | pH |
|---|---|---|---|---|---|---|---|
| | | | | Total | Reducing | Sucrose | |
| | | % | % | % | % | % | |
| Salmon Arm (Turner) | 1931 | 17.2 | 0.22 | 13.18 | 9.67 | 3.45 | 4.06 |
| | 1932 | 15.9 | .14 | 14.37 | 12.11 | 2.26 | |
| | Max. | 18.0 | .24 | 14.82 | 12.39 | 3.75 | |
| | Min. | 15.4 | .11 | 12.52 | 9.21 | 1.91 | |
| Vernon (Goodenough) | 1931 | 15.5 | .24 | 12.31 | 10.30 | 2.01 | 3.90 |
| | 1932 | 14.7 | .16 | 13.10 | 10.07 | 3.03 | |
| | Max. | 16.0 | .27 | 13.40 | 10.32 | 3.26 | |
| | Min. | 14.4 | .14 | 11.55 | 9.25 | 1.05 | |
| Oyama (Towgood) | 1931 | 17.0 | .25 | 13.61 | 10.06 | 3.52 | 4.10 |
| | 1932 | 13.0 | .13 | 12.01 | 9.06 | 2.95 | |
| | Max. | 17.5 | .26 | 13.66 | 10.69 | 4.06 | |
| | Min. | 12.6 | .11 | 11.75 | 8.82 | 2.79 | |
| Winfield (Coe) | 1931 | 18.2 | .23 | 14.70 | 10.57 | 4.13 | 4.20 |
| | 1932 | 12.6 | .14 | 11.03 | 9.78 | 1.24 | |
| | Max. | 18.5 | .23 | 14.71 | 11.37 | 4.94 | |
| | Min. | 12.0 | .13 | 10.55 | 9.67 | 0.88 | |

* Determined on the fresh pulped fruit.

TABLE 3.—RELATION OF SKIN COLOUR AND SUGAR CONTENT OF DELICIOUS APPLES

| Skin colour grade | Reducing sugar | Sucrose as invert | Total sugar |
|---|---|---|---|
| | % | % | % |
| Extra fancy | 12.39 | 2.43 | 14.82 |
| Fancy | 12.00 | 2.38 | 14.38 |
| Cee | 12.00 | 1.91 | 13.91 |

TABLE 4.—ANALYSES OF APRICOTS AND PEACHES

| Fruit | Year | Insoluble solids | Soluble solids | Sugar as invert | | | Acid as malic | Ash | Pectin | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total | Reducing | Sucrose | | | | |
| | | % | % | % | % | % | % | % | % | |
| *Apricots* | | | | | | | | | | |
| Blenheim (Summerland) | 1932 | | | 9.87 | | | 0.85 | | | |
| Blenheim | 1937 | 1.48 | 15.3 | 11.30 | | | 1.04 | .74 | .77 | |
| Royal (Summerland) | 1937 | 1.31 | 16.1 | 11.74 | | | 1.11 | .69 | .73 | |
| Average of 16 lots* | 1934 | | 12.0 | 9.07 | 7.98 | 1.85 | 1.60 | | | 3.68 |
| *Peaches* | | | | | | | | | | |
| Valiant (Summerland) | 1932 | | | 7.13 | | | .57 | | | |
| Vedette (Summerland) | 1932 | | | 8.16 | | | .69 | | | |
| Veteran (Summerland) | 1932 | | | 10.35 | | | .54 | | | |
| 4108 (Summerland) | 1932 | | | 10.49 | | | .49 | | | |
| *J. H. Hale (Summerland) | 1934 | | 11.1 | | | | .73 | | | |
| *Elberta (Summerland) | 1934 | | 10.9 | | | | .75 | | | |
| *Average of 50 lots | 1934 | | 10.7 | 8.92 | 2.79 | 6.09 | .68 | | | |

* Analyzed at shipping maturity.

TABLE 5.—RELATION OF MATURITY OF CHERRIES TO SUITABILITY FOR PROCESSING

| Variety | Soluble solids at processing maturity | Colour of bleached product | Soluble solids of over-mature fruit for processing | Colour of bleached over-mature fruit |
|---|---|---|---|---|
| Royal Ann | 14.5 | Straw yellow | 20.2 | Straw yellow |
| Bing | 14.6 | Straw yellow | 23.8 | Strong pink |
| Lambert | 15.3 | Straw yellow | 20.2 | Strong pink |
| Deacon | 11.8 | Straw yellow | 18.3 | Strong pink |

TABLE 6.—COMPARISON OF SUGAR CONTENT OF ITALIAN PRUNES AT FULL MATURITY IN YEARS 1935 AND 1936

| | Prunes floating in 20° S. brine | | Prunes floating in 35° S. brine | | Prunes sinking in 35° S. brine | |
|---|---|---|---|---|---|---|
| | 1935 | 1936 | 1935 | 1936 | 1935 | 1936 |
| Percentage of crop | 56.9 | 26.27 | 25.4 | 16.5 | 17.7 | 57.23 |
| Total solids by refractometer | 10.6 | 14.10 | 18.3 | 21.3 | 23.2 | 27.48 |

TABLE 7.—RELATION OF BRINE SEPARATION GRADES TO SUGAR AND ACID CONTENT OF ITALIAN PRUNES

| Strength of brine | Soluble solids | Acid as malic |
|---|---|---|
| °S. | % | % |
| 15° Floaters | 12.07 | 1.11 |
| 20° Floaters | 14.70 | 0.94 |
| 25° Floaters | 16.82 | 0.94 |
| 35° Floaters | 17.52 | 0.94 |
| 35° Sinkers | 21.04 | 0.94 |

TABLE 8.—COURSE OF RIPENING OF ITALIAN PRUNES INTENDED FOR DEHYDRATION

| Date harvested | Soluble solids | Total acid as malic | pH |
|---|---|---|---|
| | % | % | |
| Sept. 13 | 18.8 | 1.17 | 3.39 |
| Sept. 21 | 21.0 | 1.02 | 3.50 |
| Sept. 26 | 22.0 | 0.94 | 3.52 |
| Oct. 1 | 21.3 | 0.90 | 3.60 |
| Oct. 4 | 22.2 | — | — |

TABLE 9.—ANALYSES OF GRAPE JUICE

| Variety | Year | Soluble solids | Sugar as invert | | | Acid as tartaric | Tannin | Ash | pH |
|---|---|---|---|---|---|---|---|---|---|
| | | | Total | Reducing | Sucrose | | | | |
| | | % | % | % | % | % | % | % | |
| Angevine | 1935 | 16.8 | | | | .61 | .021 | | |
| Agawam | 1937 | 19.1 | 16.87 | 16.77 | .10 | 1.32 | .035 | | |
| *Burgunder | 1936 | 16.5 | 15.48 | 15.48 | 0.00 | .79 | .012 | | |
| Burgunder | 1937 | 16.5 | 15.35 | 15.17 | .18 | .73 | .011 | | 3.02 |
| Burgunder | 1938 | 12.6 | 11.55 | 11.29 | .26 | .51 | | | |
| Blau Frankisch | 1938 | 18.8 | 17.22 | 17.05 | .17 | .74 | .027 | .22 | 3.38 |
| *Campbell Early | 1935 | 15.5 | | | | .69 | .041 | | |
| Campbell Early | 1937 | 15.0 | 13.16 | 13.16 | 0.00 | 1.15 | .073 | | 3.28 |
| Campbell Early | 1938 | 17.7 | 16.03 | 15.50 | .53 | .60 | | | |
| Chasselas Rough | 1937 | 13.4 | 12.05 | 12.05 | 0.00 | .97 | .012 | | |
| Concord | 1937 | 15.9 | 14.38 | 14.20 | .18 | .98 | .035 | | 3.01 |
| Delaware | 1937 | 17.8 | 16.32 | 16.25 | .07 | .83 | .019 | | |
| Fredonia | 1935 | 15.7 | | | | .52 | .052 | | |
| Fredonia | 1937 | 15.0 | 12.48 | 11.90 | .58 | 1.26 | .143 | | 3.16 |
| *Muscat Ferdinand de Lessups | 1937 | 15.8 | 14.34 | 14.34 | 0.00 | .96 | .022 | | 3.10 |
| Muscat Ferdinand de Lessups | 1938 | 14.2 | 13.10 | 13.05 | .05 | .57 | .022 | | 3.28 |
| *Muscat Ottonel | 1938 | 16.4 | 15.28 | 15.28 | 0.00 | .44 | .021 | .19 | 3.50 |
| Moore's Early | 1935 | 18.3 | | | | .49 | .031 | | |
| Niagara | 1937 | 14.6 | 13.03 | 12.36 | .67 | .73 | .032 | | |
| Ontario | 1935 | 17.8 | | | | .60 | .045 | | |
| Oberlin 595 | 1935 | 23.8 | | | | 2.25 | | | |
| Oberlin 595 | 1936 | 27.4 | 24.22 | 24.22 | 0.00 | 1.75 | .172 | | |
| Oberlin 595 | 1937 | 20.4 | 17.84 | 17.84 | 0.00 | 1.68 | .085 | | 3.13 |
| Oberlin 595 | 1938 | 28.2 | 25.34 | 25.34 | 0.00 | 1.83 | .208 | .47 | 3.28 |
| Patricia | 1935 | 13.7 | | | | .50 | .052 | | |
| Pearl of Csaba | 1938 | 19.0 | 17.72 | 17.57 | .15 | .57 | .020 | | 3.50 |
| *Portland | 1935 | 15.8 | | | | .43 | .024 | | |
| Portland | 1937 | 14.1 | 12.75 | 10.01 | 2.74 | .83 | .019 | | 3.10 |
| Portland | 1938 | 18.0 | 16.73 | 12.02 | 4.74 | .38 | .046 | .27 | 3.76 |
| *Rauschling | 1936 | 17.3 | 16.22 | 16.22 | 0.00 | .73 | .012 | | |
| Rauschling | 1937 | 14.3 | 13.23 | 13.23 | 0.00 | .64 | .015 | | 3.28 |
| Rauschling | 1938 | 13.7 | 12.43 | 12.36 | .07 | .62 | | | |
| *Riesling-Sylvaner | 1937 | 16.4 | 15.12 | 15.12 | 0.00 | .83 | .006 | | 3.08 |
| Riesling-Sylvaner | 1938 | 18.1 | 16.63 | 16.27 | .36 | .72 | | | |
| *Seibel 2838 | 1935 | 15.8 | | | | .63 | .041 | | |
| Seibel 2838 | 1937 | 13.5 | 12.08 | 12.08 | 0.00 | .64 | .021 | | |
| Seibel 2838 | 1938 | 16.3 | 15.52 | 15.30 | .22 | .50 | .023 | | 3.42 |
| *Seibel 5279 | 1936 | 19.0 | 17.57 | 17.57 | 0.00 | 1.01 | .030 | | |
| Seibel 5279 | 1938 | 18.9 | 17.18 | 17.11 | .08 | .86 | .024 | .26 | 3.30 |
| Seibel 5455 | 1936 | 18.7 | 16.85 | 16.85 | 0.00 | 1.50 | .046 | | |
| Seibel 5455 | 1937 | 14.7 | 12.71 | 12.71 | 0.00 | 1.54 | .026 | | 2.85 |
| Seibel 5455 | 1938 | 18.2 | 16.27 | 16.22 | .05 | 1.27 | .012 | .26 | 3.09 |
| Seneca | 1935 | 19.5 | | | | .72 | .041 | | |
| Sheridan | 1937 | 15.3 | 13.54 | 9.50 | 4.04 | 1.08 | .039 | | 3.00 |
| Worden | 1937 | 14.7 | 12.08 | 11.04 | 1.04 | 1.49 | .097 | | 3.16 |

* Varieties which have been found to give medium sweet wines of desirable quality.

TABLE 10.—ANALYSES OF CURRANTS—1938

| Variety | Source | Total solids | Insoluble solids | Soluble solids | Sugar as invert | | | Acid* as citric | Ash | Pectin | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total | Reducing | Sucrose | | | | |
| *Black Currants* | | % | % | % | % | % | % | % | % | % | |
| Boskoop Giant | Grand Forks | 20.06 | 7.73 | 11.9 | 5.47 | 5.47 | 0.00 | 1.51 | .99 | 1.67 | 2.98 |
| Climax | Summerland | 21.9 | 7.33 | 15.0 | | 7.49 | | 1.81 | 1.04 | 1.61 | 2.83 |
| *White Currant* | Summerland | 13.99 | 5.47 | 9.6 | 5.32 | 4.98 | 0.34 | 1.85 | .67 | .62 | 3.02 |
| *Red Currant* | Summerland | 14.05 | 5.98 | 9.0 | 6.05 | 5.78 | 0.27 | 2.04 | .69 | .60 | 3.20 |

* Anhydrous.

TABLE 11.—ANALYSES OF STRAWBERRIES AND RASPBERRIES

| Variety | Source | Year | Total solids | Insoluble solids | Soluble solids. † | Total sugar as invert | Acid as citric* | Ash | Pectin | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | % | % | % | % | % | % | % | |
| *Strawberries* | | | | | | | | | | |
| Royal Sovereign | Kelowna | 1934 | 16.34 | 2.87 | 14.07 | | 1.55 | .67 | | |
| British Sovereign | Victoria | 1937 | | 2.26 | 11.5 | 8.51 | .94 | | .66 | |
| British Sovereign | Kelowna | 1937 | | 3.07 | 10.1 | 6.10 | 1.36 | | .69 | |
| British Sovereign | Nelson | 1937 | | 4.01 | 10.6 | 6.48 | 1.47 | .61 | .74 | |
| Beauty | Nelson | 1937 | | 3.38 | 8.9 | 5.87 | 1.10 | .51 | .65 | |
| Fairfax | Nelson | 1937 | | 2.55 | 10.4 | 6.27 | 1.27 | .72 | .72 | |
| Laxton | Victoria | 1937 | | 2.01 | 7.4 | 5.51 | .66 | | .45 | |
| Red Heart | Victoria | 1937 | | 2.50 | 10.5 | 7.11 | 1.03 | | .85 | |
| *Raspberries* | | | | | | | | | | |
| Cuthbert | Summerland | 1934 | 19.52 | 6.37 | 14.16 | | 1.21 | .55 | | |
| Cuthbert | Kelowna | 1937 | | 5.97 | 9.4 | 5.62 | 1.37 | .45 | .55 | |
| Latham | Summerland | 1934 | 15.64 | 4.87 | 11.07 | | 1.56 | .47 | | |
| Lloyd George | Summerland | 1934 | 16.15 | 4.50 | 12.70 | | 2.10 | .57 | | |
| Lloyd George | Summerland | 1938 | 13.02 | 5.21 | 9.6 | 4.74 | 1.98 | .63 | .65 | 3.25 |
| Newburg | Summerland | 1938 | 13.93 | 5.78 | 9.5 | 5.10 | 1.65 | .56 | .70 | 3.18 |
| Taylor | Summerland | 1938 | 14.05 | 6.31 | 9.5 | 4.95 | 1.91 | | .68 | 3.10 |
| Lloyd George | Kelowna | 1937 | | 5.79 | 9.9 | 6.66 | 1.28 | .42 | .53 | |
| Viking | Kelowna | 1937 | | 5.37 | 10.4 | 7.07 | 1.29 | .43 | .56 | |

† Determined on juice of ground sample.
* Anhydrous.

# GREENHOUSE FERTILIZER STUDIES OF CELERY[1]

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Greenhouse investigations of the food requirements of crop plants often lead to valuable conclusions as to what elements are required for optimum growth, and in what quantities. A greenhouse is the ideal place in which to carry on such experiments, since all factors are under control and may be varied at will. Furthermore, crops may be grown under glass at all seasons and much valuable time may be saved. It is realized, however, that methods which may give ideal results under glass may not give equivalent reactions when the crop is grown on a commercial basis out of doors.

Soils vary a great deal in their texture, fertility, water-holding capacity, and ability to retain nutrient elements without leaching. Due to these properties of the soil, fertilizer experiments in the field give results which are applicable only to the plots on which the experiments were conducted, or at best, to the closely adjoining portions of land. They yield practically no information as to what is required by the individual crops for their optimum growth. The best way at the present time to show which elements are of most value to the plant is by the use of water and sand cultures.

In these investigations with celery as the crop plant, the sand culture method was used. Pure quartz sand was employed and nutrient solutions were applied each week. For comparison, plants were also grown on muck and on mineral soils to which commercial fertilizers were added. The nutrient solutions used in the sand culture experiment contained the same amounts of nitrogen, phosphorus and potash as did the commercial fertilizers applied to the soils. Very interesting results were obtained from this experiment, which involved the three soil types.

## MATERIALS AND METHODS

Twenty-seven fertilizer mixtures were employed in this work. These treatments consisted of 3 levels each of nitrogen, phosphorus and potash. Table 1 gives an elaboration of the symbols employed, the fertilizer analyses and the amounts of nitrogen, phosphorus, and potash in pounds per acre. Symbols will be used throughout for the sake of convenience.

Wooden boxes were built into the greenhouse bench in order to separate the treatments from each other. The boxes were made a tight fit to prevent, as much as possible, leaching from one box to the other. The boxes were 2 feet long, 1 foot wide, 8 inches deep for the sand, and 12 inches deep for the muck and mineral soils. The boxes, which had no bottoms, were set on cinders to facilitate drainage.

For the purpose of differentiating between the soil types, the investigation was divided into 3 parts, as follows: Quartz sand, Experiment 1; Muck soil, Experiment 2; Mineral soil, Experiment 3.

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TABLE 1.—FERTILIZER TREATMENTS SHOWING FORMULAE AND ACTIVE INGREDIENTS IN POUNDS PER ACRE

| Treatment | Formula | Pounds of N | Pounds of $P_2O_5$ | Pounds of $K_2O$ |
|---|---|---|---|---|
| 0-0-0 | 0-0-0 | 0 | 0 | 0 |
| 0-0-1 | 0-0-16 | 0 | 0 | 320 |
| 0-0-2 | 0-0-32 | 0 | 0 | 640 |
| 0-1-0 | 0-8-0 | 0 | 160 | 0 |
| 0-1-1 | 0-8-16 | 0 | 160 | 320 |
| 0-1-2 | 0-8-32 | 0 | 160 | 640 |
| 0-2-0 | 0-16-0 | 0 | 320 | 0 |
| 0-2-1 | 0-16-16 | 0 | 320 | 320 |
| 0-2-2 | 0-16-32 | 0 | 320 | 640 |
| 1-0-0 | 4-0-0 | 80 | 0 | 0 |
| 1-0-1 | 4-0-16 | 80 | 0 | 320 |
| 1-0-2 | 4-0-32 | 80 | 0 | 640 |
| 1-1-0 | 4-8-0 | 80 | 160 | 0 |
| 1-1-1 | 4-8-16 | 80 | 160 | 320 |
| 1-1-2 | 4-8-32 | 80 | 160 | 640 |
| 1-2-0 | 4-16-0 | 80 | 320 | 0 |
| 1-2-1 | 4-16-16 | 80 | 320 | 320 |
| 1-2-2 | 4-16-32 | 80 | 320 | 640 |
| 2-0-0 | 8-0-0 | 160 | 0 | 0 |
| 2-0-1 | 8-0-16 | 160 | 0 | 320 |
| 2-0-2 | 8-0-32 | 160 | 0 | 640 |
| 2-1-0 | 8-8-0 | 160 | 160 | 0 |
| 2-1-1 | 8-8-16 | 160 | 160 | 320 |
| 2-1-2 | 8-8-32 | 160 | 160 | 640 |
| 2-2-0 | 8-16-0 | 160 | 320 | 0 |
| 2-2-1 | 8-16-16 | 160 | 320 | 320 |
| 2-2-2 | 8-16-32 | 160 | 320 | 640 |

*Experiment 1*

The sand used in these experiments was pulverized quartz rock. The celery seeds were germinated in greenhouse soil and when the first true leaves had formed, the seedlings were transplanted into flats containing the quartz sand. They were fed each week with a general nutrient solution until they were about two inches high. The solution used is given in Table 2.

TABLE 2.—GENERAL NUTRIENT SOLUTION FOR SMALL SEEDLINGS

| | |
|---|---|
| Calcium nitrate, $CaNO_3$ | 102.30 gm. |
| Magnesium sulphate, $MgSO_4$, $7H_2O$ | 40.70 gm. |
| Superphosphate (16%) | 63.34 gm. |
| Muriate of potash | 15.97 gm. |
| Boric acid, $H_3BO_3$ | 0.257gm. |
| Manganese sulphate, $MnSO_4$, $4H_2O$ | 0.037gm. |
| Water | 40.00 gallons |

When the plants were about two inches tall, they were transplanted into the quartz sand boxes—three plants to each box. This was done on May 27, 1938, and the first feeding of the specially prepared nutrient solutions was made on the following day.

The solutions were made up in such a way that after 13 weeks' growth, the plants in each treatment would have received in total nutrients an amount equivalent to that shown in Table 1.

Table 3 shows the amount of the elements in parts per million which was applied weekly to plants in the 1-1-1 (4-8-16) treatment for the first 4 weeks.

TABLE 3.—PARTS PER MILLION OF ELEMENTS IN SOLUTION FOR THE 1-1-1 TREATMENT FOR THE FIRST FOUR WEEKS

| | | | | | |
|---|---|---|---|---|---|
| N | 44.5 | Ca | 400.0 | Zn | 0.1 |
| P | 39.0 | S | 203.0 | Fe | 8.3 |
| K | 142.5 | Cl | 706.0 | Cu | 0.1 |
| Mg | 96.4 | Mn | 0.2 | B | 1.5 |

Table 4 represents the solution which was applied as the 1-1-1 treatment during the first 4 weeks. Solutions for the other treatments were made up by varying the amounts of nitrogen, phosphorus and potash.

TABLE 4.—CONCENTRATION OF STOCK SOLUTIONS AND THE AMOUNT OF EACH USED IN MAKING UP THE 1-1-1 TREATMENT

| Chemical | Grams per litre | Amount of stock solution in 5000 cc. distilled water |
|---|---|---|
| $NH_4NO_3$ | 90.0 | 7.06 ccs. |
| $KH_2PO_4$ | 35.0 | 24.44 ccs. |
| $K_2SO_4$ | 50.0 | 41.46 ccs. |
| $MgSO_4$ , $7H_2O$ | 70.0 | 69.75 ccs. |
| $CaCl_2$ | 75.0 | 73.80 ccs. |
| $MnSO_4$ , $2H_2O$ | 0.62 | 5.50 ccs. |
| $CuSO_4$ , $5H_2O$ | 0.333 | 3.77 ccs. |
| $ZnSO_4$ | 0.25 | 4.97 ccs. |
| $FeCl_3$ , $6H_2O$ | 5.0 | 24.20 ccs. |
| $H_3BO_3$ | 1.0 | 42.88 ccs. |

In the case of the no-potash treatments, orthophosphoric acid was used as a source of phosphorus. This solution was made up by diluting 10 cc. of the acid to 1000 cc. and applying 39.3 cc. of the stock solution for the single application.

In the case of 0-2-1, 1-2-1 and 2-2-1, increasing the level of phosphorus to 2 would have supplied too much potash from the potassium phosphate. To overcome this difficulty, a single level of phosphorus was supplied as $KH_2PO_4$ and the remainder as $H_3PO_4$. In the treatments receiving no $K_2SO_4$, the sulphur content was necessarily lowered. This was brought up to normal by adding sufficient sodium sulphate. In the case of the double application of K, the sulphur content was slightly higher than in the rest of the treatments. This was the only element which fluctuated, apart from N, P, and K. However, this fluctuation was relatively unimportant.

At the end of the first 4 weeks' growth, the concentration of nitrogen, phosphorus and potash was increased by 2.45 times the original and so maintained for the remaining 9 weeks. The concentration of the minor elements was not varied throughout the growing season. Distilled water was applied each day to provide sufficient moisture for the plants.

The pH of the solutions was adjusted to 5.5 by adding the appropriate amount of N/10 NaOH to each solution. These solutions were applied each week to the plants at the rate of 600 cc. per plant.

Measurements of height were made on July 5, July 19, and August 1. The length and weight of the roots were determined at harvest on August 1, after the roots had been carefully washed out of the sand.

*Experiment 2*

The muck soil used in this experiment was brought from Ste. Clothilde de Chateauguay. This soil may be classified as fairly well decomposed muck. McKibbin and Stobbe (8) state: "This soil is equal or superior to the soil of any other area examined in this province." The fertilizer mixtures shown in Table 1 were applied at the appropriate rates and worked into the upper 2 inches of soil. The beds were then saturated with water several times and allowed to stand for a week before the plants were set in them. Three plants were set in each box on November 30, 1938. The plants were watered with tap water when necessary.

Measurements were made on the height of the plants on February 9 and 22, and on March 8 and 22.

*Experiment 3*

The same procedure was followed as in Experiment 2, except that instead of muck soil, mineral soil was placed in the boxes. This soil was a good quality greenhouse compost made up of garden loam and well decayed manure.

Since there was a temperature gradient towards one end of the house, the muck and mineral soil plots were randomized, as were the treatments on the two soil types.

## REVIEW OF LITERATURE

Blake, Nightingale and Davidson (1) found that apple trees which were fed a nutrient solution lacking potassium but otherwise complete, developed as rapidly during the first 2 months of the experiment as did those trees which were fed with a nutrient solution lacking phosphorus or magnesium. Later these trees which were grown under potash deficient conditions began to be superior to those grown under phosphorus and magnesium deficient conditions. None of the trees grown under deficient conditions produced as rapid or as vigourous a growth as did those grown with a complete nutrient solution.

Davis, Hill and Johnson (3) grew strawberry plants under normal conditions for one season and then subjected them to low potassium conditions. These plants were able to cope with the situation to an almost efficient degree, but such was not the case with regard to phosphorus or magnesium.

Gregory (5) found that the effect of deficiency in reducing both the tiller number and leaf area of barley occurred in the decreasing order of N, P, K. Decrease in potassium in all series studied led to an increase in sodium uptake.

Comin (2) considered potash to be of most value on muck soil.

The Sections of Horticulture, Soils, Botany and Entomology of the Michigan Station (11) recommend the use of a commercial fertilizer mixture

containing some phosphate, but high in potash to produce a better yield and better quality of celery than can be obtained by the use of manure alone. The proper ratio of phosphate to potash in the mixture depends chiefly on the time of producing the crop and on the reaction of the soil. They state that an excess of phosphate is likely to produce an undersized crop.

Hoare (6) states that nitrogen and phosphorus are regarded as being more important for celery than potash.

## EXPERIMENTAL RESULTS

*Experiment 1*

*Influence of treatments on growth*

*(a)* Height

Since space does not permit, the results of all the measurements will not be tabulated; only figures representing the measurements at harvest will be given prominence, and comments will be made on the measurements at other dates only if they deviate in characteristics from those shown. It should be mentioned that the figures which appear in the tables relative to the effects of the elements on growth are not actual measurements but rather values used in the statistical analysis. Fisher's analysis of variance (4) was used and the significance tested by the $z$ value.

TABLE 5.—EFFECT OF NITROGEN, PHOSPHORUS AND POTASH ON THE GROWTH IN HEIGHT OF PLANTS GROWN IN SAND CULTURE

| | | | | | |
|---|---|---|---|---|---|
| 0% N | 169.6 | 0% P | 198.6 | 0% K | 249.9 |
| 4% N | 545.6 | 8% P | 576.9 | 16% K | 493.2 |
| 8% N | 569.8 | 16% P | 509.5 | 32% K | 541.9 |

Throughout the whole growing season, nitrogen and phosphorus proved to be extremely necessary for the growth in height of the plants. The importance of potash was not evident until about the middle of July, since previous to this date, the plants did almost as well without potash as with it. From the middle of July until harvest, the plants which received no potash in the nutrient solution rapidly deteriorated, the leaves turning yellow and the petioles and leaves drooping.

In Table 5 the difference required for significance is 124.1. Therefore it can be seen that the 4-8-16 fertilizer gave the most significant, though not the maximum response. The response was not as great between the 0 and 16% potash treatments as between the 0 and 4% nitrogen or the 0 and 8% phosphorus treatments.

*(b)* Weight

TABLE 6.—EFFECTS OF NITROGEN, PHOSPHORUS AND POTASH ON THE WEIGHT AT HARVEST OF TOPS OF PLANTS GROWN IN SAND CULTURE

| | | | | | |
|---|---|---|---|---|---|
| 0% N | 8.0 | 0% P | 13.1 | 0% K | 42.8 |
| 4% N | 411.1 | 8% P | 519.7 | 16% K | 347.2 |
| 8% N | 569.2 | 16% P | 455.5 | 32% K | 598.2 |

In Table 6 the difference required for significance is 314.3. The presence *versus* absence of nitrogen, phosphorus and potash is highly significant. It is interesting to note that 0% potash gave somewhat better results than 0% nitrogen and 0% phosphorus, but 16% potash did not result in an increase of significant proportion. A quantity of potash greater than 16% was necessary to bring about a significant difference over and above the zero level as shown by the results of the 32% potash application. The combination of 4% nitrogen, 8% phosphorus and 32% potash brought about the greatest significant weight. The double application of phosphorus had a slightly depressing effect on the weight of the plants.

Since 16% of potash was required to give the greatest significant height and 32% for the greatest significant weight, it appears that potash is required in large amounts to give body to the plants.

A count made on July 5 of all leaves which stood more than one inch above the surface of the sand revealed that 4% nitrogen and 8% phosphorus resulted in an increased number of leaves when compared with the zero treatments. The double applications of these elements had a very slightly depressing effect. There was no significant difference between presence and absence of potash on the leaf count at this date.

*Ratios and Correlations*

The ratio of length of top to length of root varied with the different treatments. In most cases the ratio was greater than unity only when the 3 elements were present.

The ratio of weight of top to weight of root varied considerably more than the length ratio. This is due presumably to the fact that the roots were air-dried overnight at room temperature before being weighed. Since some of the root systems were much larger and more bushy than others, they retained more moisture, which influenced the results. However, even here the ratios were larger when all 3 of the elements were present in the treatment.

The correlation of length of top to length of root was highly significant with a coefficient of 0.9180. The correlation of weight of top to weight of root was just as significant with a coefficient of 0.9116.

Thus, for each small change in the size of root, there is a corresponding change in the size of top. This is of great importance inasmuch that any factor which affects the root adversely results in a much decreased growth of plant.

*Condition of roots*

The lack of nitrogen, phosphorus and potash tended to produce small, brownish root systems. When all 3 elements were present, the root systems were large, succulent and white.

The analysis for length of root showed that potash did not affect the length, but on the other hand an analysis for weight showed that a heavy application of potash was necessary before the weight was significantly increased. A further examination of the root system showed something of considerable interest. The length and weight of the roots may not have been unduly affected by potash, but potash had a decided effect on texture.

Figure 1 shows the difference between the 1-1-0 and the 1-1-1 root systems. This shows clearly that the root system lacking potash consisted of long, stringy, coarse roots with very few short, stubby rootlets, and the 1-1-1 root system, which was fed potash, consisted of many fine rootlets which penetrated throughout the soil in all directions supplying the plant with an abundance of water and soil nutrients.

*Deficiency symptoms*

*(a)* Nitrogen

In the series lacking nitrogen but receiving both phosphorus and potash, the plants were small, pale green to yellowish white, and of no value. This was on July 16.

*(b)* Phosphorus

Plants in the series lacking phosphorus were small and of a pale green colour. Many of the leaves had a mottling of bronze.

*(c)* Potash

The plants in the series lacking potash grew normally until about the fifth of July before the deficiency became noticeable. This deficiency was characterized by pale yellow to green leaves and weak stems which were unable to support the leaves, which consequently had a droopy appearance. Plants in treatments high in nitrogen but lacking potash seemed to be the first to show the deficiency symptoms. The plants very quickly deteriorated once the potash reserve, which they had built up while being fed the general nutrient solution during the seedling stage, was used up.

*Condition of plants*

The plants in the following treatments at time of harvest were small and of no value:

| | | |
|---|---|---|
| 0-0-0 | 0-2-0 | 1-2-0 |
| 0-0-1 | 0-2-1 | 2-0-0 |
| 0-0-2 | 0-2-2 | 2-0-1 |
| 0-1-0 | 1-0-0 | 2-0-2 |
| 0-1-1 | 1-0-1 | 2-1-0 |
| 0-1-2 | 1-0-2 | 2-2-0 |

It is interesting to note that in the above treatments there are no more than 2 elements in any one. It seems that a balance is required before normal growth can take place. An excess of one element does not seem to make up for a deficiency of another.

The plants in the following treatments had good vigorous growth at the time of harvest:

| | | |
|---|---|---|
| 1-1-0 | 1-2-1 | 2-1-2 |
| 1-1-1 | 1-2-2 | 2-2-1 |
| 1-1-2 | 2-1-1 | 2-2-2 |

The plants in the 1-1-0 treatment were lacking in potash, but seemed to be able to keep up with the amounts of nitrogen and phosphorus present. Possibly when 2 elements are properly balanced, the deficiency of the third is not quite so noticeable. However, when the root system for the 1-1-0

treatment is examined (Figure 1), it is difficult to understand how such a badly developed root system could support a vigorous plant.

Maximov (7) cites Mitscherlich as suggesting that the increase in one of the nutrient elements slightly augments the effects of the other nutrient substances. Thus, in the case of nitrate deficiency, a potash fertilizer may increase the yield, though according to the law of the minimum, this should not be the case.

Since the potassium can be replaced by sodium to some extent, the explanation for the continued growth of the plants in the 1-1-0 treatment might be found. In making up the nutrient solutions, the sulphur content was maintained in the absence of potassium sulphate by adding an appropriate amount of sodium sulphate. The sodium added here may have been enough, along with nitrogen and phosphorus, to give good growth.

*Experiment 2*

*Effect of treatments on plants*

The treatments used on the mineral and muck soils were the same as those used in the sand cultures except that on the 2 soils commercial fertilizers were applied instead of nutrient solutions.

Table 7.—Effect of nitrogen, phosphorus and potash at harvest on the height of plants grown on muck soil in the greenhouse

| | | | | | |
|---|---|---|---|---|---|
| 0% N | 661.6 | 0% P | 302.8 | 0% K | 653.3 |
| 4% N | 677.5 | 8% P | 868.7 | 16% K | 725.7 |
| 8% N | 712.5 | 16% P | 880.1 | 32% K | 672.6 |

The difference required for significance is 44.3. Nitrogen applications did not show any great improvement in yield except towards the end of the growing season, when the double application gave a significant increase over the zero treatment.

From February 9 until harvest, the addition of 8% of phosphorus gave a very marked increase in the size of the plants, but the double application did not make any improvement in yield.

The only effect due to the addition of potash was increased height at harvest when 16% gave a significant increase over the zero treatment. At the other 3 dates potash did not increase the height of the plants grown on muck soil.

According to the survey conducted by McKibbin and Stobbe (8) in the Sherrington-Ste. Clothilde area whence came the muck soil used in the experiment, the values for potash content of the soil ranged from 0.007% to 0.250%.

A test made by Morgan's Universal Soil Testing System (9), which gave a reading of less than 150 lbs. per acre, confirmed the fact that the soil was very low in potash. The addition of potash did not greatly increase the size of the plants. As previously shown in connection with the sand cultures, potash is extremely necessary for good growth of celery, yet on the muck soil used in this experiment, the plants apparently did quite well without a large application of potash.

Figure 2 shows the size of the plants in the 0-0-0, 0-0-1, and 0-0-2 treatments at harvest. The background is laid out in 2-inch squares.

Figure 3 shows the effects of adding phosphorus to the treatments in Figure 2. Figure 4 represents the results obtained by adding nitrogen to the treatments in Figure 2. The increase in size is almost negligible.

As shown in Figure 5, the addition of phosphorus to the treatments represented in Figure 4 resulted in a very great increase in growth.

The above results seem hard to believe of plants grown on muck soil since crops, especially celery, usually respond favourably to applications of potash. To check these results, celery plants were transplanted into 1-gallon crocks containing muck soil from 2 widely different sources and in different stages of decomposition. Fertilizers, representing 5 different treatments, were applied. In the following table, the columns with the heading "A" are the total of the measurements of 3 plants grown on muck soil obtained from the Agronomy Department, Macdonald College, while column "B" represents growth on muck soil from Ste. Clothilde de Chateauguay.

TABLE 8—TOTAL HEIGHT IN CMS. OF THREE PLANTS PER TREATMENT ON MUCK SOIL FROM TWO SOURCES

| Treatment | April 24 | | May 11 | | May 27 | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| 1-0-1 | 13.1 | 20.2 | 18.0 | 45.9 | 38.1 | 81.8 |
| 1-0-2 | 14.1 | 19.2 | 16.6 | 54.0 | 31.1 | 88.9 |
| 1-1-0 | 45.2 | 48.6 | 90.8 | 93.7 | 103.5 | 102.9 |
| 1-1-1 | 43.1 | 43.0 | 87.8 | 89.2 | 102.3 | 94.7 |
| 1-2-0 | 44.9 | 46.7 | 89.3 | 91.0 | 95.9 | 99.0 |

These figures show the very great increase in the height of the plants when phosphorus was applied. There was a slight decrease in size of the plants when potash was added to the nitrogen and phosphorus. The increase in size of plants by substituting phosphorus for potash was not as evident in the plants grown on muck from source "B" as it was in the greenhouse experiment on muck soil which has already been described. However, some increase occurred.

The effect of nitrogen, phosphorus and potash on leaf count is similar to that shown for these 3 elements on height of plants. Hence it would seem that there is a very definite relation between the size of the plant and the number of leaves produced.

*Experiment 3*

*Effect of treatments on the plants*

Mineral soil, as would be expected, gave very different results from the fertilizer treatments from those which were obtained on the muck soil.

TABLE 9.—EFFECT OF NITROGEN, PHOSPHORUS AND POTASH AT HARVEST ON THE HEIGHT OF PLANTS GROWN IN THE GREENHOUSE ON MINERAL SOIL

| | | | | | |
|---|---|---|---|---|---|
| 0% N | 859.5 | 0% P | 769.1 | 0% K | 907.7 |
| 4% N | 780.8 | 8% P | 825.7 | 16% K | 790.1 |
| 8% N | 754.6 | 16% P | 800.1 | 32% K | 697.1 |

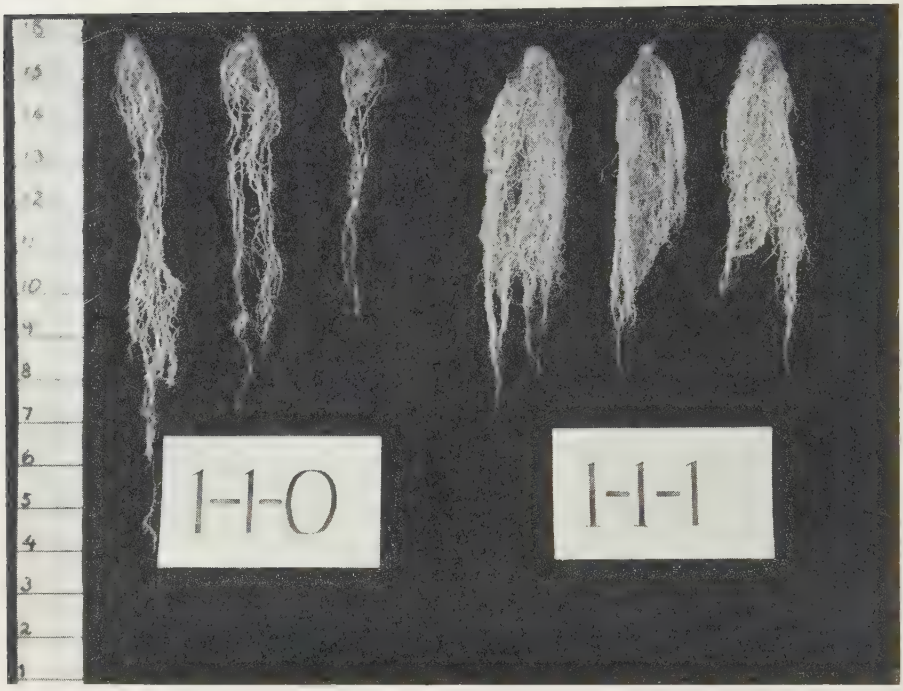


FIGURE 1. Showing the effect of the lack of potash on the roots (left) as compared with roots which had received potash (right).

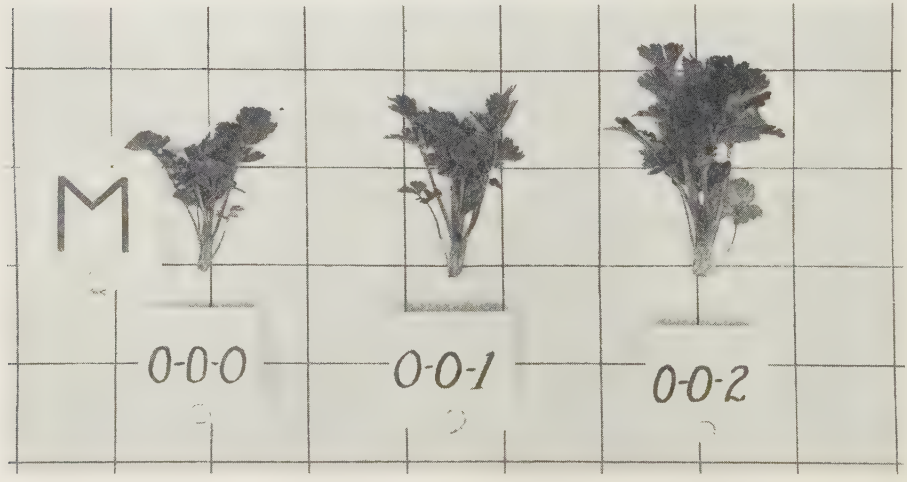


FIGURE 2. There is very little difference in plant size between the presence and absence of potash. The plants are small in the absence of nitrogen and phosphorus.

FIGURE 3. The addition of phosphorus has greatly increased the size of the plants. (Compare with Figure 2.) Potash in addition to phosphorus has increased the body of the plants somewhat.

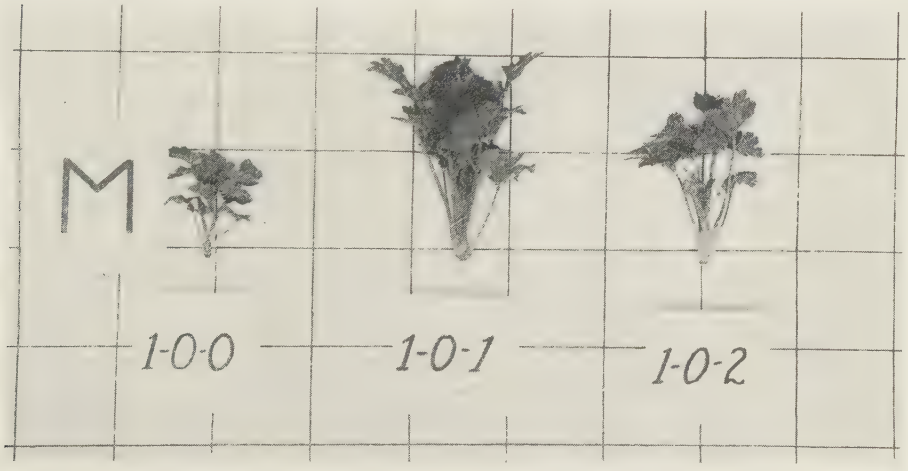


FIGURE 4. Nitrogen alone and in combination with potash did not result in large plants.

FIGURE 5. When phosphorus is applied to the series represented in Figure 4, growth is very substantially increased. This shows the relative importance of phosphorus as compared with the other two elements.

The difference required for significance is 85.50. Eight per cent nitrogen gave significant decreases in height on March 8 and 22. On the first two dates (February 9 and 22), the decrease reached almost the odds of 20 : 1.

On February 9 and 22, the addition of phosphorus increased the height. On March 8, the increase was hardly significant, while at harvest, phosphorus did not produce any significant difference.

Potash gave the most striking results of all. Good yields were obtained without any potash. The addition of 16% decreased the yields significantly while a further addition of 16% gave yet another significant decrease. Figure 6 shows the type of decrease observed. It must be mentioned that this is the most outstanding decrease due to potash additions but serves well to illustrate the point, since other potash treatments show the same type of decrease.

Nitrogen did not affect the leaf count markedly, though it had a slightly depressing influence. The addition of 8% of phosphorus increased the number of leaves, while 16% decreased the number. An increase of potash

to 16% and to 32% decreased the number of leaves very markedly each time.

The leaf count and the height measurements would suggest that the mineral soil already contained sufficient nitrogen and potash. Further additions of these 2 elements decreased the yields. An 8% application of phosphorus improved the size. Since greenhouse compost, containing manure, was used, these results would indicate that this mineral soil, with a good application of manure, would require 800 lbs. of superphosphate to yield a good crop of celery. It is quite possible that a small application of phosphorus might have given a greater response since there are some indications that an increase of phosphorus somewhat decreased the yield.

FIGURE 6. On mineral soil the addition of potash had a detrimental effect on yield. The plants did very well without an application of potassium.

## DISCUSSION

Four per cent nitrogen, 8% phosphorus and 16% potash at the rate of one ton of fertilizer mixture (4-8-16) per acre gave the best results with celery growing on quartz sand.

Potash applications did not bring about any improvement during the first 5 weeks. Apparently the plants had stored up sufficient potassium during the seedling stage to tide them over a part of the time when they were receiving no potash in the nutrient solution. This is in keeping with the results of Blake et al. (1) and Davis et al. (3).

Potash deficiency symptoms in celery as brought out in this work compare somewhat with those in potatoes as pointed out by Rohde (10); *e.g.*, yellowing of older leaves, dwarfing of the plant, a weakened root system, and a marked development of deficiency symptoms in the presence of an abundance of nitrogen.

There seems to be no question but that nitrogen, phosphorus and potash are necessary for the formation of strong, healthy, well-developed root systems.

Since the quartz sand contained little, if any, of the elements necessary for growth, the results derived here show what celery actually requires for optimum growth. The varying results on the muck and mineral soils show what the plants require for growth on those particular soils. Hence if potash does not seem to be required in the fertilizer mixture, as shown by the muck and mineral soil plots in the greenhouse, it is no criterion that the plant does not require and use potash.

## CONCLUSIONS

1. Plants were grown in quartz sand and fed weekly with nutrient solutions. The results indicated that the equivalent of one ton per acre of 4-8-16 fertilizer mixture gave the best results.

2. Root systems were affected by the deficiencies of nitrogen, phosphorus and potash, being small and brownish.

3. Potash deficiency tended to produce poorly developed root systems with few rootlets.

4. Phosphorus was the limiting factor on muck soil in the greenhouse, while additions of nitrogen and potash to mineral soils adversely affected growth.

5. In many instances, increasing phosphorus beyond a certain limit had a detrimental effect on growth.

6. In some of the studies, an increase of potash did not improve the yield or quality, but it had no detrimental effect on growth, except when it was applied to the mineral soil plots in the greenhouse.

7. A proper balance of nitrogen, phosphorus and potash is required to give the best results. This balance can be ascertained only by trial on the different types of soil and under the different climatic conditions which are likely to exist from year to year.

## ACKNOWLEDGMENTS

The writer wishes to express his appreciation to those who made this work possible, more especially to Prof. H. R. Murray of the Horticulture Department, who suggested the problem and gave assistance in the greenhouse studies; to Prof. R. Summerby of the Agronomy Department, for

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# RASPBERRY NUTRITION[1]

## IV. CAN THE CUTHBERT RASPBERRY BE SAVED IN COASTAL BRITISH COLUMBIA?

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As part of a program undertaken to ascertain the causes of raspberry failures in coastal British Columbia, the following studies on raspberry nutrition and management were carried out in the Plant Nutrition Section of the Department of Horticulture, The University of British Columbia.

The Cuthbert has for many years been British Columbia's outstanding raspberry. It is still preferred by the trade. Most shippers, canners, and the trade generally refuse other raspberries if Cuthberts are available. Because of its general merit, growers were loth to think of discarding the Cuthbert and planting other varieties. Nevertheless, many of them have been advocating its general abandonment, claiming that it can no longer be grown satisfactorily in British Columbia. The present investigation was undertaken in part to see whether the Cuthbert should be discarded in favour of some other variety, or whether it could be grown profitably provided that some system of good management were practised.

### MATERIALS AND METHODS

Young raspberry plants (suckers) of the Cuthbert variety were used throughout the investigation. These plants were obtained from a source recommended by Dominion and Provincial Government agricultural officials as being the best source in the Fraser Valley from which to obtain stock plants.

The project was divided into four phases, as follows:

*A. Sand Pot Cultures*

The plants were set out in large pots filled with well-washed sand, in the spring of 1937. These plants were fed with various nutrient solutions, in each of which, other than the checks, one of the nutrients considered necessary to plant growth was either omitted or given in excess. Hoagland's nutrient solution was used as the basis, and by varying this solution the treatments given were as follows:

Complete nutrient solution
Nitrogen—deficient
Phosphorus—deficient
Potassium—deficient
Calcium—deficient
Sulphate—deficient
Nitrogen—excess, 5x

[1] Contribution from the Department of Horticulture, University of British Columbia, Vancouver, B.C. Read to the Horticultural Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939.
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Phosphorus—excess, 5x
Potassium—excess, 5x
Calcium—excess, 5x
Complete plus boron, 5 p.p.m.; manganese, 2 p.p.m.; and zinc, 1 p.p.m.
Complete plus boron, 5 p.p.m.
Complete plus manganese, 2 p.p.m.
Complete plus zinc, 1 p.p.m.
Complete plus aluminum, 10 p.p.m.

The object of this experiment was to see whether symptoms similar to those appearing in affected field plantings could be produced artificially.

During the spring of 1938, the plants were carefully removed and half of those receiving each treatment were placed in a 50/50 mixture of the original sand and peat moss; the others were replaced in the original sand.

*B. Soil Pot Cultures*

Plants were set out in large pots filled with a heavy clay soil taken from a notoriously poor raspberry plantation located at Hatzic in the Fraser Valley, in 1937. These plants were treated with different kinds of fertilizing materials, including micro elements, to note whether any beneficial response could be obtained. The materials used were as follows:

Check—soil as taken directly from the field.
Soil sifted to remove foreign matter, decayed roots, etc.
Soil steam sterilized.
Ammonium sulphate applied at the rate of 800 lb. per acre.
Ammonium sulphate plus iron sulphate, applied at the rate of 250 and 50 lb. per acre respectively.
Iron sulphate applied at the rate of 50 lb. per acre.
Potassium sulphate applied at the rate of 200 lb. per acre.
Manganese sulphate applied at the rate of 25 lb. per acre.
Zinc sulphate applied at the rate of 25 lb. per acre.
Free sulphur applied at the rate of 200 lb. per acre.
Gypsum applied at the rate of 2000 lb. per acre.
Dry lime sulphur (spray material) applied at the rate of 500 lb. per acre.
Boron applied at the rate of 25 lb. per acre.
Copper lime dust applied at the rate of $\frac{1}{4}$ oz. per plant.
Copper carbonate applied at the rate of $\frac{1}{4}$ oz. per plant.
Cheshunt compound applied at the rate of 1 quart per plant.
Ferrous ammonium sulphate $Fe(NH_4)_2(SO_4)_2\ 6H_2O$ at the rate of 150 lb. per acre.
Check—a greenhouse compost used in the U.B.C. greenhouses.

*C. Field Plots*

In the spring of 1937 a field plot of somewhat over one acre was planted on the horticultural grounds at the University of British Columbia, in order to determine the effects of various fertilizer, cover-crop and cultural treatments under field conditions, in contrast to the above controlled pot experiments. The soil is a fairly uniform glaciated loamy sand, with a very low water-holding capacity. It has a reaction of pH 5.70, a field capacity of about 17% moisture, and plants wilt in it at around 12% moisture.

The procedure was as follows:

Plot A

Fertilizer Treatments (clean cultivation)

In order to ascertain the effect of various fertilizer applications, treatments were as indicated below. Each treatment was separated by a buffer row. The basic fertilizer used was 5-10-5 at the rate of 800 lb.

per acre, with the exception of the ammonium sulphate plot. All plots were the same size.

Check
Complete fertilizer (5-10-5)
Superphosphate plus muriate of potash (nitrogen-deficient)
Ammonium sulphate plus superphosphate (potash-deficient)
Ammonium phosphate (16-20-0) plus muriate of potash plus free sulphur (calcium deficient).
Ammo-Phos. plus muriate of potash
Complete (5-10-5) plus boron at the rate of 25 lb. per acre
Complete plus manganese at the rate of 15 lb. per acre
Complete plus sulphur at the rate of 200 lb. per acre
Complete plus gypsum at the rate of 500 lb. per acre
Ammonium sulphate only at the rate of 800 lb. per acre
Ammonium sulphate plus iron sulphate at the rate of 250 and 50 lb. per acre respectively.
Magnesium sulphate at the rate of 1½ oz. per plant

Plot B

Cover-crop Treatments

The object of this experiment was to determine the value of cover-cropping as a practice in raspberry culture. The plot was divided into sections and each section was seeded to clover, rye, alfalfa, soy-bean, followed by corn and vetch respectively. A clean-cultivated section was also left as a check.

Nitrogen Applications at Different Times of the Year

In order to determine the best time of the year to apply nitrogen, each of the sections in Plot B was subdivided vertically into 4 series:

Series 1 received a complete fertilizer, 5-10-5, in March.

Series 2, 3 and 4 all received an 0-12-10 fertilizer in March as a basic application. Series 2 then received ammonium sulphate in May, Series 3 received ammonium sulphate in July, while Series 4 received ammonium sulphate in September. As before, the 5-10-5 fertilizer at the rate of 800 lb. per acre was used as the basic fertilizer, and equivalent amounts were used in the 0-12-10 application.

The Effect of Liming Raspberries

It was desired to evaluate the use of lime on raspberry plantings on the light upland soils which are typical of many areas in British Columbia. In order to do this, the sections of Plot B were divided horizontally. The upper half did not receive lime, while the lower half received an application at the rate of 2,000 lb. hydrated lime per acre.

Thus it was anticipated that in Plot B the best cover crop to use, the best time of the year to apply nitrogen, and the response of raspberries to liming under the conditions of the experiment could be determined, and that the inter-relations of one to the other would be elucidated.

Experiments with Peat Moss

In the spring of 1938 a trench was dug and peat moss to a depth of 3 to 4 inches was scattered on the bottom and worked into the soil. New plants were set out in this trench. One bale of peat was used for a 90-foot row. Peat was also dug in around various plants scattered throughout the plots. (Magnesium sulphate was also dug in around several plants throughout the plots, at the rate of 4 oz. per plant.)

*D. Samples of Fraser Valley Soil and Raspberry Canes*

To correlate the work further with conditions throughout the Fraser Valley, samples of canes and the soil on which they were growing, were collected and brought in to the laboratory for analysis. Similar samples were also sent in directly by growers.

## RESULTS OF EXPERIMENTS

*A. Sand Cultures*

During the year 1937 only the plants which received the luxury feeding of phosphorus showed a marked increase in growth over the check plants. They were outstanding (Figures 1 and 2). The nitrogen-deficient, phosphorus-deficient and sulphur-deficient series showed marked deficiency symptoms (Figures 3 and 4) similar to those exhibited by certain field plantings which have been observed.

These symptoms are quite in accord with observations on other plant material reported by other workers (1, 2, 3, 7).

Nitrogen deficiency caused small, stunted plants with small, yellowish green leaves, which later showed excessive anthrocyan pigmentation.

Phosphorus deficiency initially caused a dark-green leaf, which soon showed anthrocyan pigmentation on the underside of the leaf. A purpling of both stems and leaves became pronounced. Plants were small and weak.

Sulphur deficiency was indicated by a yellowish chlorosis of the leaves,

FIGURES 1 AND 2. One-year-old Raspberry Plants grown in Sand Cultures showing the effects of mineral excesses and deficiencies.

FIGURE 1. Left: excess phosphorus. Centre: excess nitrogen. Right: complete nutrient.

FIGURE 2. Left: excess calcium. Centre: excess potash. Right: complete nutrient.

FIGURES 3 AND 4. One-year-old Raspberry Plants grown in Sand Cultures showing the effects of mineral excesses and deficiencies.

FIGURE 3. Left: sulphur deficient. Left centre: phosphorus deficient. Right centre: nitrogen deficient. Right: complete nutrient.

FIGURE 4. Left: calcium deficient. Centre: potash deficient. Right: complete nutrient.

first starting along the veins. The leaves became very papery. Fair growth was made, but the canes were very slender.

Potash deficiency did not develop until late in the season, but when it did develop it did so rapidly. It was characterized by a bronze spotting and scorching of leaf tips and edges.

The series which received additions of micro-elements—boron, manganese, zinc, copper, etc.—showed some, but no really significant increase in growth (Figures 5 to 7).

During 1938, that is, the second year after planting, the best specimens were found in the series receiving complete nutrient solution, complete nutrient plus boron, manganese and zinc, and complete nutrient plus boron. What appeared to be some form of mosaic ran through all the series, with the exception of the above-mentioned.

In every case the plants set out in the sand/peat mixture showed greater and more vigorous growth than the correspondingly treated ones in the sand alone.

*B. Soil Pot Cultures*

None of the plants in this series were normal, but both years the sterilized pots produced the best plants. In 1938 the sifted soil, and the gypsum, borax, copper-lime dust and cheshunt compound treatments produced fairly good cane growth. Plants in all other series continued to be stunted and weak, with small reddened leaves.

FIGURES 5 – 7. One-year-old Raspberry Plants grown in Sand Cultures. Showing the effects of additions of micro-elements to the complete nutrient.

FIGURE 5. Left: complete + boron. Centre: complete + boron, manganese and zinc. Right: complete nutrient.

FIGURE 6. Left: complete + zinc. Centre: complete + manganese. Right: complete nutrient.

FIGURE 7. Left: complete + aluminum. Centre: phosphorus deficient. Right: complete nutrient.

Observations made on the roots at the time of re-potting in the spring of 1938 were as follows:

Check—roots poor.
Sterilized soil—good root formation.
Ammonium sulphate—moderate rooting.
Ammonium sulphate plus iron sulphate—good root formation.
Iron sulphate—moderate root formation.
Potassium sulphate—very poor rooting.
Manganese sulphate—moderate rooting.
Zinc sulphate—stunted roots.
Gypsum—good roots.
Lime sulphur—long, slender roots, fairly good.
Free sulphur—stunted roots, sulphur not oxidized.
Boron—roots poor.
Copper-lime dust—moderate rooting.
Copper carbonate—moderate rooting.
Cheshunt compound—good roots.
Ferrous ammonium sulphate—good roots.

The peat/sand mixture in 1938 without exception increased growth from 10 to 100%.

*C. Field Plots*

Fertilizer Treatments (clean-cultivated)

Canes in this plot made poor growth in 1937, but in 1938 made excellent growth. They were all irrigated in 1938, and the splendid response would indicate that a plentiful moisture supply is of paramount importance in raspberry production.

The nitrogen-, phosphorus-, and potash-deficient rows showed distinctive deficiency symptoms corresponding to those in the sand cultures.

The greatest growth resulted in canes receiving a complete fertilizer (5-10-5) plus sulphur, and complete plus gypsum treatment.

Those plants which received magnesium sulphate also responded with strong cane growth, as did the rows treated with peat.

That a definite response to fertilizer treatments was obtained can be observed from Table 1.

Table 1.—Yield of raspberries in relation to fertilizer treatments, 1939

| Treatment | Yield (lb.) |
|---|---|
| Ammonium phosphate plus muriate of potash | 195 |
| 5-10-5 plus free sulphur | 169 |
| 5-10-5 plus gypsum | 159 |
| Ammo-Phos plus muriate of potash plus sulphur | 154 |
| 5-10-5 plus boron | 149 |
| Ammonium sulphate only | 131 |
| 5-10-5 plus manganese | 128 |
| 5-10-5 | 106 |
| Ammonium sulphate plus iron sulphate | 104 |
| Superphosphate plus muriate of potash | 76 |
| Ammonium sulphate plus muriate of potash | 74 |
| Ammonium sulphate plus superphosphate | 65 |
| Check | 64 |

The benefit of sulphur-carrying fertilizers and ammonium phosphate is quite pronounced.

The above yields can also be taken as indicative of growth response.

Cover-crop Treatments

In this section the clean-cultivated patch gave the best response. This was followed by the vetch cover crop. The yields from these plots are indicative of the response to the various treatments.

TABLE 2.—YIELD OF RASPBERRIES IN RELATION TO COVER-CROP TREATMENTS

| Treatment | Yield (lb.) | Treatment | (Yield (lb.) |
|---|---|---|---|
| Clean cultivation | 592 | Soy-bean cover crop | 201 |
| Vetch cover crop | 295 | Alfalfa cover crop | 143 |
| Clover cover crop | 227 | Rye cover crop | 105 |

Nitrogen Applied at Different Times of the Year

To date this experiment indicates that in the light upland soils of coastal British Columbia, the spring is the best time to apply nitrogen, if only one application a year is to be given.

TABLE 3.—YIELDS OF RASPBERRIES IN RELATION TO NITROGEN APPLICATIONS AT DIFFERENT TIMES OF THE YEAR

| Fertilizer treatment | Yield from cover-crop treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| | Clean cultivation | Clover | Alfalfa | Rye | Vetch | Soybean | Total |
| 5-10-5 April | 174 | 45 | 67 | 40 | 127 | 52 | 504 |
| 0-12-10 April<br>Am. sulphate *May* | 196 | 88 | 27 | 24 | 97 | 98 | 530 |
| 0-12-10 April<br>Am. Sulphate *July* | 138 | 53 | 40 | 28 | 32 | 65 | 356 |
| 0-12-10 April<br>Am. Sulphate *Sept.* | 83 | 39 | 9 | 13 | 38 | 27 | 209 |

The April application of the complete fertilizer, 5-10-5, and the basic application of 0-12-10 in April followed by ammonium sulphate in May, gave the best results. Fall fertilizing with nitrogen does not appear to have given much benefit.

The Effect of Liming Raspberries

The results of liming the plots are shown in Table 4.

This table clearly indicates that liming has proved detrimental in this experiment. This is accounted for by the fact that the reaction of the unlimed plots is not unfavourable to raspberry production (pH 5.7). Moreover, soil analyses showed that available phosphorus was lowered by the liming (8).

TABLE 4.—THE INFLUENCE OF LIMING ON YIELDS OF RASPBERRIES

| | Yield from cover-crop treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| | Clean cultivated | Vetch | Clover | Alfalfa | Rye | Soybean | Total |
| Limed | 244 | 131 | 97 | 66 | 50 | 129 | 718 |
| Unlimed | 348 | 164 | 129 | 77 | 54 | 112 | 885 |

Experiments with Peat

The row established over peat is not yet in full bearing, so comparative yields cannot be reported. The healthy vegetative condition of the canes has been reported on above.

*D. Samples of Canes and Soil from Outside Points*

The causes of raspberry failure in the patches from which samples were collected and sent in by growers for analysis, were many. These have been reported in a previous paper, and further work substantiates the former findings (5).

## CONCLUSIONS

The raspberry decline problem in coastal British Columbia in many cases can be attributed to nitrogen, phosphorus, sulphate and potash deficiencies. The first two are the most common. The raspberry responds to luxury feeding of phosphorus in particular.

Nitrogen, phosphorus, potash and sulphate deficiency can readily be detected in the raspberry by foliar diagnosis. Growers should become more familiar with these deficiency symptoms than they are at present.

There is a suggestion that the plants in this experiment which received the micro-elements were more resistant to mosaic disease than those which did not receive them. Further work along this line would be warranted. That mosaic is a definite factor to be contended with means that a rigid selection of plants must be exercised. Some permanent reliable source of healthy stock plants would be of great benefit to the raspberry grower.

The observations on root formation in the badly depleted Hatzic soil, and the indications of root stimulation from copper-, iron- and sulphur-containing compounds may be considered evidence of the value of these substances in such a soil. Whether these compounds acted in this case as stimulants or as soil disinfectants cannot be stated.

The beneficial effect of peat throughout is noteworthy. This could be due to the increase of aeration in the heavy Hatzic soil, and also to the increase in the water-holding capacity of the soil. However, the applications of peat used in order to accomplish this effect were heavy.

The results from the field plots definitely indicate that water is probably the chief limiting factor in raspberry plantings in the light, upland soils of British Columbia's coastal regions. Plants which only struggled along without irrigation, flourished luxuriantly under irrigation, with the same fertilizer treatments.

The B.C. coastal soils are, in the main, relatively low in phosphorus. Nevertheless, the form in which this element is applied is significant in raspberry nutrition. Ammonium phosphate, for instance, gives a good response. It may be said in general that phosphorus should be applied in combination with, or soon followed by, nitrogen, and perferably in some sulphur-carrying fertilizer. The soils in question are low in sulphates (5) and hence the plants respond to sulphates. This high phosphorus requirement of the raspberry was established in the sand culture experiments reported, and is again reflected by the detrimental effects of liming, which lowered the available phosphorus of the soil (8).

The clean-cultivated plots gave better results than the cover-crop series. It must be borne in mind, however, that these plots were well fertilized and watered. For the majority of growers, where economy in fertilizers is necessary and where no irrigation is practised, the use of cover crops is still to be recommended. In such cases the water-holding capacity of the soil must be increased, and the added organic matter of the cover crops will increase the water-holding capacity of the soil as well as reduce leaching losses of the added nutrients. Of the cover crops tried, vetch has proved superior to the others.

It has been shown to date that nitrogen applied early, in a complete fertilizer, or a basic application of fertilizer in the form of 0-12-10 followed by an application of nitrogen in early May, gave the best results. It must be recalled, however, that the plants which received nitrogen in July and September did not receive any other nitrogen. During the period of rapid growth, when nitrogen is used heavily, they did not receive any. The writer is of the opinion that while a spring application of nitrogen is essential, later applications, as well as the one in the spring, could be used to advantage (4). A sound practice would be to use either a low-nitrogen complete fertilizer or an 0-12-10 fertilizer in early spring, followed at intervals with light applications of ammonium sulphate. Careful foliar diagnosis will indicate when this should be applied. Fall fertilization with nitrogen does not appear to be advisable. The nitrogen, in all probability, is leached away by the fall rains before it can be of much benefit to the plants.

Liming did not seem to be of much value. It was actually detrimental. This can be accounted for by the fact that the reaction of the unlimed plots, pH 5.7, is not unfavourable to raspberry production. Soil analyses, moreover, showed that the available phosphorus was lowered by the liming. This danger from liming, even though the reaction may indicate a need for lime, has already been pointed out (5).

While peat is obviously of advantage in that it adds organic matter and increases the water-holding capacity of a light soil, the amounts necessary to do this make its use impracticable for the average grower, unless he be located where he can obtain it merely for the cost of hauling it himself. Most growers must rely on cheaper methods to obtain organic matter, such as cover cropping, or the use of some mulching material.

There seems to be no one cause from which all the declining raspberry plantings are suffering. It is a case of individual diagnosis and remedy for each section, and in many cases for each plantation or part of a plantation. General recommendations are inadvisable.

The conclusion is reached that the foregoing experiments have definitely established the fact that the Cuthbert raspberry can still be grown profitably in coastal British Columbia, provided that it receives proper cultural treatment. It is essential to use healthy planting stock and a continuous, reliable source of such stock is needed. There are no grounds at present on which to discard the Cuthbert raspberry in B.C. or discourage its planting. It is still our best berry.

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# DORMANCY IN WHEAT AND BARLEY VARIETIES IN RELATION TO BREEDING[1]

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## INTRODUCTION

Modern plant breeding methods involve consideration of an ever-increasing number of characters. As standards become more exacting and competition more severe, it becomes necessary to perfect varieties in particulars which had previously been thought of minor importance or non-genetical. The dormancy of grain varieties is a character that only recently has achieved a position of breeding significance.

Dormancy, or "after ripening"[4] of grain, is important in those regions where prolonged wet weather may occur at the time the crops ripen. Occasionally on the plains of Western Canada, wet harvest weather causes large losses due to sprouting of stooked and windrowed grain waiting to be threshed. The losses are particularly severe in the cooler moister areas. Furthermore, some varieties suffer far more damage than others.

Economically it is desirable to have varieties which remain dormant for several weeks following maturity. Marquis, which for years has been the most extensively used wheat variety in Western Canada, has a long dormancy period and is popularly considered highly resistant to after-harvest sprouting. There are, however, other standard varieties which do not possess high "sprouting resistance." From the viewpoint of both the farmer and the plant breeder, it seemed desirable at this time to make a study of dormancy in varieties which are being used commercially or as parental material in crosses.

## LITERATURE REVIEW

The literature on dormancy is fairly extensive, and it is only necessary here to consider a few of the more pertinent papers.

Harrington (3) compared the effect of moist conditions at harvest time on varieties of durum and bread wheat which were stooked in the field. In the 1927 experiment the varieties were ranked from high to low resistance to sprouting as follows: Marquis 70, Kitchener, Red Fife, Red Bobs, Reward, Renfrew, Pelissier (durum), Mindum (durum), Early Red Fife, Kubanka (durum), Quality, Ruby, and Garnet. In 1931 the order of resistance to sprouting was Marquis, Reward, Ceres, and Garnet.

Deming and Robertson (1) studied the dormancy of 7 varieties of wheat, 13 of barley, and 3 of oats. The varieties were harvested when ripe and plantings made in moist sand each day after maturity for 60 days in

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[4] After-ripening is a state of dormancy of the embryo and is used synonomously with the term "dormancy" in this paper. "After-ripening" refers to the dormancy of a mature seed in the presence of conditions favouring germination and no apparent physical impediments (such as hard seed coat) to germination.

1928, and 40 in 1929 and 1930. If a seed did not emerge 10 days after planting, it was considered to be dormant. The wheat varieties ranged from Marquis with considerable dormancy to 3 varieties with no dormancy. The barley varieties showed a range from no dormancy to dormancy for 11 days after harvest. Two oat varieties germinated immediately but the third was dormant for 27 days.

Scholz (5) tested 143 varieties of bread wheat and 6 durum varieties. Germination tests were started immediately after harvest and continued at 10-day intervals using moist filter paper. The durum varieties used had a longer after-ripening period than the bread wheats. No relation was found between the length of the after-ripening period and either spring or winter habit or earliness of ripening. After-ripening was not found to be associated with the moisture content of the grain.

Freistedt (2) conducted very extensive tests over a number of years on the dormancy of both spring and winter barleys. He used moist filter papers for the germination tests; he also used sheaves kept in a moistened chamber. A number of Japanese varieties proved to have a long after-ripening period. Winter barleys were tested for germination from the milk to the fully-ripe stage. In a genetic analysis conducted on the $F_2$ of 4 crosses of spring barley, dormancy proved recessive. In one cross 1 factor seemed involved, and in the other crosses 2 factors.

Navolotskii and Navolotskaja (4) demonstrated injury to the seed as a result of germination in the ear. *Triticum durum* tended to germinate readily in the ear. *T. persicum* under excessive humidity was also defective in this respect, while *T. dicoccum* was resistant to sprouting.

## MATERIALS AND METHODS

1. In the fall of 1937, a preliminary test of dormancy was conducted at the University of Saskatchewan on 5 varieties of bread wheat, Marquis, Garnet, Reward, Thatcher, and Reliance, and 1 durum variety, Mindum. Heads of all of the varieties were collected on the same day within an area of 5 acres. Each head taken was discarded unless it was at the stage of maturity when the lower kernels are indented with difficulty by the thumb-nail.[1] The seeds were rubbed out from each head on the day it was collected.

Petri dishes containing sand were used as germinators. A single germination test of each variety consisted of 2 dishes containing 50 seeds each. The sand in the dishes was kept as uniformly moist as possible. The temperature of the room varied from 20° to 22° C. On the day that the varieties were harvested (August 3), a germination test was commenced. Further tests were started after this at intervals of 4, 8, 12, 16, 21, 26, and 36 days after maturity. Germination counts were made at 2, 4, 6, and 30 days after establishing a test. A seed was considered germinated when the roots had emerged $\frac{1}{8}$-inch.

[1] This is a standard test of maturity which is reliable and widely used.

2. In 1938 the experiment was enlarged to include more varieties of wheat and some barley varieties as well. Following are the wheat varieties used: *T. vulgare*—Marquis, Reward, Garnet, Thatcher, Apex (Sask 1703), Apex (Sask 1789), Renown, and Reliance; *T. durum*—Mindum, Golden Ball, and Pelissier; *T. persicum*—Black Persian. The barley varieties were: 2-rowed awned—Hannchen and Rex; 6-rowed awned—Regal, O.A.C. 21, and Trebi; 6-rowed hooded—Sixty-Day and 2 hooded hybrids. One of these hybrids, designated TC. III-36-46, was a selection from the cross Trebi × Colsess. The other, called TS. III-36-9, was a selection from the cross Trebi × Sixty-Day.

As in 1937, no spikes were used in either wheat or barley unless the lower kernels of the spike were indented with the thumb-nail with difficulty. All the barley varieties were taken on one day, August 5. Similarly, all the wheat varieties were collected on August 11. The heads were threshed by rubbing the seeds out. In order to harden them the kernels were kept dry for a day previous to starting the germination test.

Throughout the 1938 experiments, duplicate samples of 50 seeds each were used for testing each variety. As already mentioned, the first germination tests of wheat and barley were carried out at the hard-ripe stage. Further germination tests were started at regular intervals, as indicated in Table 2. Germination was carried out on a basement floor in a greenhouse. Sand was spread evenly on the floor to a depth of one inch and moistened. The seeds were placed on this, and a petri dish put over them. The sand was kept moist by watering with a sprinkling can every few days. Excessive moisture was drained off. The moisture conditions throughout the tests tended to be quite uniform. The temperature of the sand ranged from 16° to 17° and that of the atmosphere from 17° to 18° C.

It will be noted that the sand temperatures were 4° to 5° lower in the 1938 tests than in the 1937 tests. It is possible that the after-ripening period of some varieties was slightly shortened in 1937 as compared with 1938 due to this temperature difference. It is considered that this is a relatively unimportant point, especially since the data from the 2 years was considered separately in making varietal comparisons.

### 1. RESULTS FROM THE 1937 TEST ON WHEAT

The results of the 1937 wheat study are presented in Table 1. All varieties maintained a 2-day dormancy from maturity until 26 days after maturity, with the exception of Garnet, which showed 15% germination 12 days after maturity and increasing amounts thereafter, and Reliance, which showed 12% germination after 16 days. Mindum showed little 4-day dormancy and practically no 6-day dormancy at any time after maturity. Garnet showed only 21% germination in 4 days immediately after maturity, but in the tests started subsequent to 4 days after maturity this variety showed no 4-day or 6-day dormancy. Reliance germinated at 4 and 6 days to a much lower extent than Garnet until 12 days after maturity, but thereafter behaved like Garnet. Reward and Thatcher behaved alike as to 4-day dormancy, holding it well until 8 days after maturity. But Reward germinated in 6 days to a much less extent than Thatcher until 8 days after maturity. Marquis germinated least readily of all the varieties and excelled the nearest competitor, Reward, by resisting germination at 2 days until after 21 days after maturity.

Summarizing the 1937 tests shows: (1) Mindum with the greatest 2-day dormancy and very little dormancy for more than 2 days at any time after maturity; (2) Garnet with relatively little dormancy excepting for 2 days during the first 12 days after maturity; (3) Reliance with distinctly more dormancy than Garnet; (4) Thatcher with 4-day dormancy continuing until 8 days after maturity; (5) Reward and Marquis with 6-day dormancy continuing for 8 days after maturity. Thus a short wet spell would be expected to affect Mindum the least and Garnet the most, whereas a longer wet spell would injure Mindum the most and the other varieties in the order Garnet, Reliance, Thatcher, Reward and Marquis.

TABLE 1.—COMPARISON OF SIX WHEAT VARIETIES FOR GERMINATION AFTER MATURITY IN 1937*

| Days after maturity | Days after start of germination test | Marquis | Garnet | Reward | Thatcher | Reliance | Mindum |
|---|---|---|---|---|---|---|---|
| | | | | per cent germination | | | |
| 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4 | 0 | 21 | 0 | 0 | 13 | 63 |
| | 6 | 0 | 54 | 3 | 37 | 35 | 92 |
| | 30 | 27 | 98 | 36 | 96 | 82 | 95 |
| 4 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| | 4 | 0 | 44 | 0 | 0 | 14 | 51 |
| | 6 | 0 | 77 | 3 | 42 | 47 | 91 |
| | 30 | 26 | 99 | 38 | 94 | 83 | 98 |
| 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4 | 4 | 90 | 2 | 0 | 59 | 41 |
| | 6 | 8 | 96 | 7 | 28 | 77 | 77 |
| | 30 | 45 | 99 | 57 | 97 | 99 | 100 |
| 12 | 2 | 0 | 15 | 0 | 0 | 0 | 0 |
| | 4 | 35 | 98 | 47 | 50 | 61 | 47 |
| | 6 | 84 | 98 | 82 | 96 | 98 | 95 |
| | 30 | 97 | 98 | 93 | 98 | 100 | 98 |
| 16 | 2 | 0 | 43 | 1 | 0 | 12 | 2 |
| | 4 | 62 | 100 | 100 | 99 | 100 | 31 |
| | 6 | 100 | 100 | 100 | 100 | 100 | 92 |
| | 30 | 100 | 100 | 100 | 100 | 100 | 97 |
| 21 | 2 | 2 | 79 | 4 | 1 | 7 | 1 |
| | 4 | 98 | 100 | 99 | 91 | 97 | 63 |
| | 6 | 100 | 100 | 100 | 98 | 97 | 94 |
| 26 | 2 | 83 | 95 | 81 | 67 | 86 | 17 |
| | 4 | 99 | 97 | 100 | 99 | 100 | 84 |
| | 6 | 99 | 98 | 100 | 100 | 100 | 99 |
| 36 | 2 | 100 | 100 | 100 | 99 | 100 | 92 |
| | 4 | 100 | 100 | 100 | 99 | 100 | 99 |

* Date of maturity—Aug. 3, 1937.

### 2. RESULTS ON WHEAT HARVESTED AT MATURITY IN 1938

The 1938 results on wheat harvested at maturity are presented in Table 2. A general comparison of these results with those obtained in 1937 reveals for 1938 less complete dormancy immediately after maturity but a tendency for dormancy to continue a few days longer than in 1937.

The three durum varieties behaved in 1938 much as Mindum did in 1937 with very little 4-day dormancy and practically no 6-day dormancy at any time after maturity. It is of interest that immediately at maturity the durums showed more germination in 2 days than at any later period up to 84 days after maturity.

The bread wheat varieties showed much variation. Compared collectively with the durums, the bread wheats maintained more dormancy during the first 8 days after maturity and less thereafter. Reliance was unique in showing practically no dormancy at any time, excepting for 2 days during the period from 4 to 36 days after maturity. Garnet showed a 2-day dormancy for 20 days after maturity and a high degree of 6-day dormancy at maturity, but otherwise resembled Reliance. The remaining varieties, including Marquis, Reward, and those with rust resistance, had distinctly more dormancy. Renown retained much 6 and 30-day dormancy until 20 days after maturity, and Apex 1789 retained dormancy similarly until 12 days after maturity. Marquis, Reward, Thatcher, and Apex 1703 showed much 6-day dormancy 4 days after maturity, but Thatcher resembled Reliance in having practically no 30-day dormancy immediately after maturity. The 4-day germination results show roughly the same varietal differences in dormancy from the 4th to the 20th day after maturity. Subsequent to 20 days after maturity, the 2-day germination results indicate the differences between varieties.

Black Persian, representing the species *T. persicum*, gave results closely resembling those of the bread wheat averages.

The data of Tables 1 and 2 are summarized in Table 3 to show the varieties in approximate ranking for resistance to germination. For the purpose of this summary, germination percentages above 40% were considered to indicate non-dormancy. It is of interest that two of the new rust-resistant wheats, Renown and Apex 1789, ranked highest in 1938, the only year they were tested. Considering both years, the ranking of varieties is identical, excepting that in 1937 Marquis slightly excelled Reward and in 1938 the reverse occurred.

### 3. RESULTS ON BARLEY HARVESTED AT MATURITY, 1938

The results of the sprouting tests of barley are presented in Table 4. The data show greater relative differences in dormancy among the barley varieties than were found among the wheat varieties. After being under

TABLE 2.—COMPARISON OF DIFFERENT VARIETIES OF WHEAT FOR GERMINATION AFTER MATURITY, 1938*

| Days after maturity | Days after start of germination test | *Triticum vulgare* | | | | | | | | *T. durum* | | | *T. persicum* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Marq. | Rew. | Gar. | That. | A 1703 | A 1789 | Ren. | Rel. | Min. | Pel. | G. Bl. | Bl. Pr. |
| | | Per cent germination | | | | | | | | | | | |
| 0 | 2 | 0 | 0 | 3 | 0 | 1 | 2 | 0 | 29 | 8 | 11 | 10 | 2 |
| | 4 | 6 | 2 | 5 | 3 | 6 | 11 | 0 | 88 | 41 | 45 | 64 | 7 |
| | 6 | 8 | 7 | 9 | 23 | 9 | 21 | 2 | 92 | 78 | 83 | 93 | 17 |
| | 30 | 40 | 15 | 44 | 81 | 33 | 50 | 15 | 95 | 99 | 100 | 100 | 37 |
| 4 | 2 | 4 | 1 | 10 | 0 | 0 | 2 | 0 | 4 | 1 | 7 | 0 | 5 |
| | 4 | 22 | 22 | 50 | 12 | 16 | 10 | 2 | 97 | 49 | 65 | 53 | 20 |
| | 6 | 33 | 29 | 56 | 49 | 24 | 18 | 5 | 98 | 84 | 84 | 80 | 24 |
| | 30 | 47 | 36 | 80 | 88 | 44 | 36 | 23 | 100 | 100 | 97 | 100 | 33 |
| 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| | 4 | 58 | 31 | 84 | 39 | 49 | 16 | 17 | 97 | 37 | 17 | 43 | 60 |
| | 6 | 69 | 40 | 87 | 55 | 63 | 24 | 25 | 100 | 76 | 62 | 80 | 71 |
| | 30 | 77 | 46 | 96 | 92 | 78 | 47 | 41 | 100 | 95 | 87 | 100 | 72 |
| 12 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4 | 72 | 65 | 93 | 54 | 64 | 37 | 8 | 96 | 33 | 24 | 32 | 42 |
| | 6 | 81 | 72 | 95 | 60 | 71 | 47 | 10 | 100 | 63 | 61 | 83 | 54 |
| | 30 | 88 | 74 | 98 | 88 | 76 | 61 | 20 | 100 | 98 | 94 | 93 | 57 |
| 20 | 2 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 4 | 94 | 76 | 98 | 74 | 84 | 69 | 41 | 97 | 52 | 25 | 59 | 77 |
| | 6 | 96 | 79 | 100 | 82 | 86 | 72 | 43 | 99 | 71 | 60 | 88 | 82 |
| | 30 | 98 | 82 | 100 | 100 | 96 | 81 | 51 | 100 | 97 | 95 | 98 | 83 |
| 28 | 2 | 19 | 9 | 81 | 3 | 3 | 5 | 5 | 13 | 2 | 1 | 0 | 60 |
| | 4 | 100 | 96 | 100 | 99 | 100 | 98 | 84 | 100 | 74 | 55 | 75 | 96 |
| | 6 | 100 | 96 | 100 | 99 | 100 | 98 | 86 | 100 | 83 | 87 | 97 | 96 |
| | 30 | 100 | 96 | 100 | 99 | 100 | 98 | 94 | 100 | 100 | 95 | 100 | 97 |
| 36 | 2 | 0 | 0 | 12 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 6 |
| | 4 | 97 | 99 | 100 | 99 | 93 | 97 | 89 | 99 | 69 | 59 | 75 | 96 |
| | 6 | 98 | 99 | 100 | 100 | 98 | 100 | 91 | 100 | 78 | 76 | 87 | 98 |
| 52 | 2 | 12 | 1 | 50 | 4 | 0 | 3 | 0 | 25 | 0 | 0 | 0 | 20 |
| | 4 | 98 | 100 | 100 | 98 | 99 | 97 | 94 | 100 | 22 | 29 | 58 | 98 |
| | 6 | 99 | 100 | 100 | 100 | 99 | 99 | 98 | 100 | 42 | 71 | 79 | 99 |
| 84 | 2 | 65 | 59 | 100 | 48 | 68 | 63 | 92 | 60 | 23 | 15 | 46 | 87 |
| | 4 | 100 | 99 | 100 | 100 | 100 | 99 | 100 | 100 | 93 | 68 | 100 | 100 |
| | 6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 97 | 100 | 100 |

*NOTE.—Date of maturity was August 12, 1938.

Key to abbreviations in Table 2.

Marq. — Marquis (Sask. 100)
Rew. — Reward (Sask. 1003)
Gar. — Garnet (Sask. 791)
That. — Thatcher (Sask. 1720)
A 1703 — Apex (Sask. 1703)
A 1789 — Apex (Sask. 1789)
Ren. — Renown (Sask. 1735)
Rel. — Reliance (Sask. 1851)
Min. — Mindum (Sask. 64)
Pel. — Pelissier (Sask. 109)
G. Bl. — Golden Ball (Sask. 1887)
B. Pr. — Black Persian (Sask. 1801)

TABLE 3.—SUMMARIZATION OF RESULTS ON WHEAT VARIETAL GERMINATIONS AT DIFFERENT DATES AFTER MATURITY IN 1937 AND 1938

| | Variety | The number of days which elapsed after maturity before exposure to germination conditions for 2, 4, 6 or 30 days, respectively, resulted in more than 40% germination | | | | |
|---|---|---|---|---|---|---|
| | | 2 days | 4 days | 6 days | 30 days | Rank |
| 1937 | Marquis | 26 | 16 | 12 | 8 | 1 |
| | Reward | 26 | 12 | 12 | 8 | 2 |
| | Thatcher | 26 | 12 | 4 | 0 | 3 |
| | Reliance | 26 | 8 | 4 | 0 | 4 |
| | Mindum | 36 | 0 | 0 | 0 | 5 |
| | Garnet | 16 | 4 | 0 | 0 | 6 |
| 1938 | Renown | 84 | 20 | 20 | 8 | 1 |
| | Apex 1789 | 84 | 20 | 12 | 0 | 2 |
| | Reward | 84 | 12 | 12 | 8 | 3 |
| | Blk. Pers. | 84 | 8 | 8 | 8 | 4 |
| | Apex 1703 | 84 | 8 | 8 | 4 | 5 |
| | Marquis | 84 | 8 | 8 | 4 | 6 |
| | Thatcher | 84 | 12 | 4 | 0 | 7 |
| | Reliance | 84 | 0 | 0 | 0 | 8 |
| | Mindum | 84+ | 0 | 0 | 0 | 9 |
| | Pelissier | 84+ | 0 | 0 | 0 | 10 |
| | Gold. Ball | 84 | 0 | 0 | 0 | 11 |
| | Garnet | 28 | 4 | 4 | 0 | 12 |

germination conditions for 2 days, Hannchen, Rex, and Sixty-Day showed the most ready germination while TC. III-36-46 and Trebi had the greatest resistance to germination. When a period of between 20 and 36 days had elapsed after ripening, germination in 4 days was slight for TC. III-36-46 and Trebi, moderate for Regal and almost complete for the remaining varieties.

In the 6-day test, Hannchen and Rex germinated readily, but were followed closely by Sixty-Day, TS. III-36-9 and O.A.C. 21, Regal was intermediate and Trebi and TC. III-36-46 came last. Exposure to germination conditions for 30 days resulted in Hannchen and Rex germinating almost completely whether started at maturity or at later dates, but in TC. III-36-46, Regal and Trebi only very gradually achieving this ability to germinate. The other varieties were intermediate.

In general, therefore, Rex and Hannchen possessed practically no after-ripening period, being able to sprout almost completely when germinated at maturity. Sixty-Day, TS. III-36-9 and O.A.C. 21 had a 4-day dormancy for roughly 10 to 12 days. Regal, at maturity, and for a short period after, resembled the last-mentioned group but was rather sluggish in reaching its complete ability to germinate, and maintained a 2-day dormancy until 52 days after maturity. TC. III-36-46 and Trebi exhibited the greatest reluctance to germinate, the former holding a 6-day dormancy for more than a month after full maturity.

## DISCUSSION

After-harvest sprouting is a very real problem in the grain fields of many parts of the world. In Western Canada it is desirable that the breeder take some pains to insure a considerable degree of dormancy in

TABLE 4.—COMPARISON OF EIGHT BARLEY VARIETIES FOR GERMINATION AFTER MATURITY, 1938*

| Days after maturity | Days after start of germination test | Germination percentage of varieties | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hann. | Rex | 60 Day | TC 46 | TS 9 | Regal | O.A.C. 21 | Trebi |
| 0 | 4 | 83 | 60 | 47 | 2 | 31 | 26 | 18 | 11 |
| | 6 | 91 | 75 | 63 | 5 | 37 | 40 | 55 | 26 |
| | 30 | 95 | 89 | 71 | 38 | 56 | 56 | 86 | 62 |
| 4 | 4 | 51 | 22 | 35 | 4 | 23 | 24 | 11 | 6 |
| | 6 | 80 | 59 | 51 | 6 | 35 | 34 | 27 | 9 |
| | 30 | 100 | 97 | 76 | 50 | 68 | 57 | 81 | 68 |
| 8 | 4 | 89 | 64 | 77 | 6 | 38 | 38 | 73 | 5 |
| | 6 | 98 | 88 | 88 | 13 | 49 | 55 | 83 | 9 |
| | 30 | 99 | 91 | 92 | 52 | 83 | 71 | 89 | 86 |
| 12 | 4 | 97 | 78 | 81 | 3 | 48 | 62 | 50 | 10 |
| | 6 | 100 | 94 | 90 | 8 | 83 | 73 | 90 | 25 |
| | 30 | 100 | 96 | 93 | 59 | 96 | 77 | 97 | 76 |
| 20 | 2 | 77 | 62 | 65 | 1 | 30 | 24 | 58 | 15 |
| | 4 | 99 | 86 | 96 | 6 | 91 | 59 | 93 | 36 |
| | 6 | 99 | 90 | 99 | 11 | 95 | 66 | 97 | 47 |
| | 30 | 99 | 91 | 99 | 64 | 97 | 68 | 97 | 88 |
| 36 | 2 | 41 | 39 | 43 | 2 | 37 | 6 | 21 | 9 |
| | 4 | 99 | 92 | 97 | 28 | 100 | 63 | 100 | 35 |
| | 6 | 99 | 97 | 100 | 35 | 100 | 73 | 100 | 66 |
| | 30 | 99 | 99 | 100 | 86 | 100 | 88 | 100 | 90 |
| 52 | 2 | 37 | 45 | 34 | 0 | 7 | 4 | 5 | 17 |
| | 4 | 97 | 90 | 90 | 20 | 86 | 67 | 84 | 49 |
| | 6 | 100 | 100 | 99 | 34 | 99 | 92 | 96 | 66 |
| | 30 | 100 | 100 | 100 | 83 | 100 | 97 | 97 | 91 |
| 68 | 2 | 55 | 47 | 48 | 4 | 18 | 35 | 28 | 0 |
| | 4 | 100 | 98 | 98 | 24 | 90 | 92 | 95 | 24 |
| | 6 | 100 | 100 | 100 | 62 | 100 | 99 | 100 | 61 |
| | 30 | 100 | 100 | 100 | 82 | 100 | 100 | 100 | 95 |
| 84 | 2 | 93 | 86 | 77 | 41 | 36 | 44 | 69 | 45 |
| | 4 | 100 | 98 | 100 | 95 | 91 | 93 | 100 | 91 |
| | 6 | 100 | 98 | 100 | 98 | 100 | 97 | 100 | 100 |
| | 30 | 100 | 98 | 100 | 98 | 100 | 97 | 100 | 100 |

*NOTE.—Date of maturity was August 6, 1938.

Key to abbreviations in Table 4.

Hann. — Hannchen (Sask. 229)
Rex — Rex (Sask. 1761)
60 Day — Sixty-Day (Sask. 1667)
TC 46 — TC. III-36-46
TS. 9 — TS. III-36-9
Regal — Regal (Sask. 1865)
O.A.C. 21 — O.A.C. 21 (Sask. 228)
Trebi — Trebi (Sask. 101)

any new grain varieties that are released to the public. The dormancy studies reported in this paper reveal wide differences between varieties and also show that dormancy is not a simple phenomenon.

The varietal reactions ranged from the inability of Reliance to remain dormant for more than 2 days at maturity or thereafter to the ability of Renown to hold a high degree of 30-day dormancy for 2 weeks after maturity. In the barley an equally wide range was apparent, Hannchen possessing practically no dormancy while TC. III-36-46 showed a large amount of 30-day dormancy for 12 days after maturity and high 6-day dormancy for 52 days.

The complexity of dormancy is illustrated by a comparison of the durum wheats with vulgare varieties. The durum varieties possessed no 30-day dormancy at maturity but showed some from 36 to 52 days after maturity. whereas several vulgare varieties showed a large degree of 30-day dormancy at maturity and for 12 days thereafter but none later on. On the other hand the durums had a higher degree of 2-day dormancy 84 days after maturity than did the vulgare varieties, although some of the vulgares held their 2-day dormancy for 52 days.

As some of the barley varieties are related, it is of interest to compare them briefly in this respect. Rex was derived from the cross, Velvex Hannchen, which might explain the similarity between Rex and Hannchen in their reaction to after-ripening. The results on TS. III-36-9 agree with expectation, since that variety is more or less intermediate between its parents, Sixty-Day and Trebi, in its germination characteristics. The same might be stated for TC. III-36-46. Colsess was not tested in this experiment, but Deming and Robertson (1) reported Colsess and Trebi as being similar in their dormancy period, and the results on TC. III-36-46 resemble those on Trebi.

The new stem rust-resistant varieties, Renown, Apex, and Thatcher, proved to have at least as much dormancy as the standard varieties, Marquis and Reward. While it is encouraging to find this favourable degree of dormancy in the new hybrid varieties of wheat, it must be admitted that this situation is to some extent a matter of good luck. Although weathering tests were made on all the new rust-resistant wheats before they were finally chosen for distribution to the public, dormancy as a character did not enter the picture when the original crosses were made.

It is of particular interest that among the new hybrid wheat and barley varieties of Western Canada there are some which excelled such highly satisfactory standard varieties as Marquis and Trebi in their ability to remain dormant under conditions favourable for germination. The plant breeder has a visible basis for constructive work when he recognizes the need for a certain character and has varieties expressing that character.

The paper listed as "Potassium Deficiency in Prunes, Grapes and Clover", by M. E. McCollam, was delivered in the form of an illustrated address and, at the author's suggestion, was not submitted for publication.

The paper on Raspberry Nutrition, by G. H. Harris, read to a joint meeting of the Soils and Horticultural Groups, is printed in this number. Other papers read to the joint meeting of these two groups have been published in the January, 1940, issue of Scientific Agriculture, 20: 5.

Professor J. Walker, of the University of Manitoba, was elected Chairman of the Group for 1940. The appointment of a Secretary was left to him. Please address all communications regarding suggestions for the 1940 program to Professor J. Walker.

### REFERENCES

1. Deming, G. W. and D. W. Robertson. Dormancy in small-grain seeds. Col. Agr. College, Fort Collins. Technical Bulletin 5. 1933.

2. Freistedt, P. Neue Zielsetzungen in der Gerstenzüchtung. Zeit. Zuchtg. A Pflanzenzüchtg. 20 : 2; 169-209. 1935.

3. Harrington, J. B. The comparative resistance of wheat varieties to sprouting in the stook and windrow. Sci. Agr. 12 : 635-645. 1932.

4. Navolotskii, A. V. and N. M. Navolotskaja. Breeding spring wheat to raise the germination capacity of the grain. Selektsija i Semenovodstvo (Breeding and Seed Growing). No. 9 : 25-32. 1936. In Russian. English abstract.

5. Scholz, J. The after-ripening of some wheat varieties especially Czechoslovakian. Zvlastni Otist z Casopisu Vestnik Ceskoslovenske Akademie Zemedelske. 9 : 6-7; 403-409. 1933. English summary.

## OTHER HORTICULTURAL GROUP PAPERS.

The following papers, read to the Horticultural Group of the Canadian Society of Technical Agriculturists at the Nineteenth Annual Meeting at Vancouver, B.C., June 19 to 22, 1939, have been published in previous issues of Scientific Agriculture.

Blair, D.S., Present status of the apple rootstock and double-working trials in Eastern Canada. Sci. Agr. 20 : 2; 150-154.

Dickson, G. H., Some factors affecting the dropping of McIntosh apples. Sci. Agr. 19 : 12; 712-721.

Hall, E. R., The pollination of the sweet cherry on Vancouver Island, British Columbia. Sci. Agr. 19 : 8; 524-530.

The following papers, while read to the Horticultural Group, have not yet been forwarded for publication.

Root-stock Problems in Western Canada—A. J. Mann and R. C. Palmer.

The Influence of Some Seedling Treatments on Lettuce Production—J. Walker.